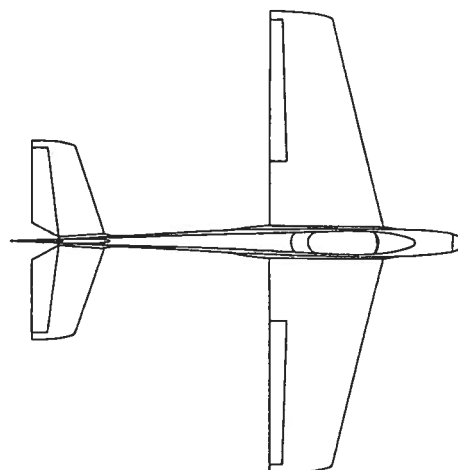


# **BUILDING A PATTERN AIRPLANE**



**BY BRUCE THOMPSON  
&  
DON ATWOOD**

**FOURTH EDITION**



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By Bruce Thompson and Don Atwood

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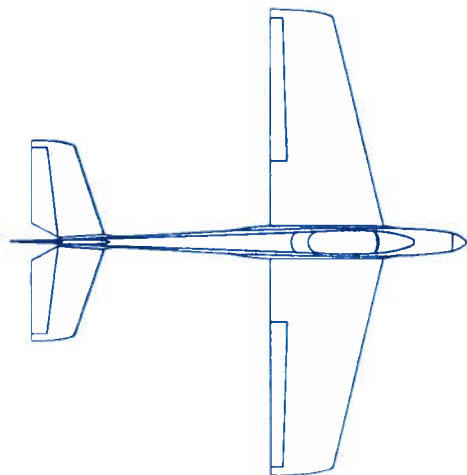
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## FOREWORD

The old adage that "the teacher learns more than the student" certainly pertains to this book. By having to think through and write down building techniques to build a pattern airplane has been an educational process.

Regarding the content, we admit we do not claim originality for any of the ideas or procedures outlined in this book. We learned them from other modelers by word of mouth, by graphic building demonstrations and from published techniques. We know that on the day this book is published someone will question our choices of materials and techniques, or claim that the procedures outlined in this book are not originally ours. It is certainly the reader's prerogative to disagree with our choices. But keep in mind, the reason we're writing this book is to introduce modelers who have never constructed a pattern airplane to this aspect of model aviation. We have used and tried each and every component and procedure outlined in this book. This is not to say that what is presented here is gospel. We're always open to new techniques and materials to improve the strength and lightness of our own airplanes and welcome suggestions from other modelers. This exchange of ideas will only help improve this publication and further the hobby. So, if after reading this book, you come up with a better construction technique than what we have described, please share it with us.

We hope you enjoy reading this book as much as we enjoyed writing it.

If you have comments, problems or suggestions on how we might be able to improve the book please send us a note via e-mail to the following address:

[bruce.Thompson@merrick.com](mailto:bruce.Thompson@merrick.com)

### **ACKNOWLEDGMENTS**

We would like to acknowledge the help of Rob Kelly and the contributors to the *K-Factor*, the newsletter of the NSRCA for their help and ideas for this book. A special thanks to Al Coelho for his invaluable help in compiling the radio information section of the book. And, without the proofreading help of Dorrie O'Brien with Write Way Publishing Inc. and Mary Scott, you wouldn't have been able to read this book.

### **DEDICATION**

This book is dedicated to our wives, Jean Marie and Georgette. Without their understanding, help and support, we would not be modeling, nor would we have written this book.

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# Chapter 1 AN INTRODUCTION TO PATTERN AIRPLANES

## WHY BUILD A PATTERN AIRPLANE?

Fly a lightweight pattern airplane once and you'll be hooked. There is nothing that compares to the sheer delight of having an aircraft perform as nimbly and precisely as a lightweight pattern airplane. Pattern airplanes are very predictable. A pattern airplane, unlike a sport airplane, will hold its position without control input, making it relatively easy to fly. However, many flyers believe these wonderful aircraft are beasts and at any moment will turn on you and join terra firma just to spite you. *Au contraire!* Many sport fliers have found that a well-trimmed pattern airplane, with correct control surface deflections and sufficient power, is much easier to fly than most of the sport airplanes.

Pattern airplanes can be enjoyed by anyone who has basic flying and building skills. Except for a few pieces of special equipment, any person who's built sport airplanes can utilize the same equipment and building materials to construct a pattern airplane. So why is it that people are intimidated by an aircraft that exhibits the docility of a high-wing trainer, but possesses the aerodynamic capability to fly the length of an airfield on its edge, in a maneuver commonly known as a "knife edge"? We asked many flyers why they haven't built a pattern airplane after they've marveled at the way they've flown. Their answers can be consolidated into the following statements:

"These airplanes are used primarily in competition. Competition equipment, no matter what it is, has the stigma of being very esoteric, and hard control."

"The exotic materials used in constructing pattern airplanes are difficult to work with and require extremely high-quality equipment."

"Wow, they're great ... look like a lot of fun to fly ... but too complex to build and nobody has a good instruction manual that has lots of pictures."

The responses to our question prompted us to write this book. It was written for those people who:

- Want to try their hand at building and flying a pattern airplane
- Are first-time pattern airplane builders.

We attempted to clarify every detail required to build a pattern airplane, and included many photos to help illustrate the construction techniques that for many years have eluded many builders.

The airplanes used for examples in this book are the "SL-1" and the "Prophecy." The SL-1 is an airplane that was popular back in the early "1990s." It was a state of the art airplane for its time. The later model airplanes incorporate the same features but are just a little larger. However, the construction details for the SL-1 can be used for a majority of the modern day pattern airplanes. Essentially any airplane with a canopy and belly pan or chin cowl can be built using the techniques shown for the SL-1. We have taken the liberty to list a number of similar configured kits to the SL-1.

Airplane	Manufacturer
Summit 120	Precision Aero Composites
Fascination	Precision Aero Composites
Odyssey	Precision Aero Composites
Omen	Precision Aero Composites
Saturn	Aero Lite Products
Pursuit 120	Aero Lite Products
Hydeout	Dixie Competition Products
EMC2	Dick Hanson Models
Hurricane	Honeycomposites, Inc.
Arch Nemesis	K & A Models

(Refer to the appendix for addresses of these manufacturers)

We chose the Prophecy as our other example because it has a number of unique design features the SL-1 doesn't have. The Prophecy, designed by Dave Guerin, is a state-of-the art airplane that is a derivative of the Jeckyl, Dr. Jeckyl and Dr. Jeckyl Phd. Refer to the index for the address of the Prophecy kit manufacturer.

We have also included construction techniques for a Typhoon 2+2. This airplane is two-meters long and had a two-meter wing span. The airplane used as an example in this book is constructed entirely of balsa wood (except for the wing tube, canopy and cowl). Refer to the index for the address of the supplier of the Typhoon 2+2 plans and specifications.

If you want to build along with the instructions in this book, just purchase a kit or plans and join in the fun of building and flying a pattern airplane.

### WHAT IS A PATTERN AIRPLANE?

Pattern airplanes are aircraft of their own design. There is no other aircraft, either full-scale or otherwise, that resembles their basic overall configuration. Pattern airplanes are designed and constructed with one purpose in mind: to perform precisely prescribed maneuvers at specific locations smoothly, efficiently and quietly. They are graceful airplanes that combine the technology of flight with the requirements of aerobatics. The demands on these airplanes are great. They must be able to be a stable flyer at both high and low speeds, yet be able to perform violent snap rolls and spins, and recover quickly. The design and configuration of these airplanes vary dramatically, which is allowed by the rules.

Generally speaking, pattern airplanes are approximately five to six feet in wing span, and possess between 700 and 1,200 square inches of wing area. They have a fuselage that varies

from four feet to two meters long, a tail moment of approximately three feet and an airfoiled horizontal and vertical stabilizer.

If you want to build and fly a pattern airplane, then take some time to watch good pattern flyers and ask them their opinion of how their airplane performs and what they like and/or dislike about it. We have yet to find a pattern flyer that won't talk forever about his plane if asked. Your fear shouldn't be to ask questions, but to find a way to escape the discussion in time to make it home for dinner! Beware however, that pattern flying is very encompassing: you'll find yourself improving your building skills in order to get the most out of your aircraft, and improving your flying skills trying to win every contest you enter.

### PATTERN AIRPLANE CONFIGURATIONS

Competition rules governing the configuration of a pattern airplane state the following. "No model may weigh more than five kilograms (11 pounds) gross, but excluding fuel, ready for takeoff. No model may have a wing span or total length longer than two (2) meters (78.74 inches)." The present rule leaves engine size and airplane configuration wide open.

Some pattern airplane designs use the plug-in wing feature, in lieu of the traditional one-piece wing configuration. The plug-in wing feature is nice if you're cramped for room while transporting an airplane: add the plug-in stabilizer feature and crating and transportation becomes very easy. The choice of an airplane, with either plug-in wings or a one-piece wing, is purely personal. But whatever choice you make, there's one rule that applies to any combination of airplane and engine: build the airplane as *light and as straight* as it can possibly be.

### WHY A LIGHTWEIGHT PATTERN AIRPLANE?

It is important to construct a pattern airplane as light as possible because a light airplane will:

- Dampen faster in windy conditions;

- Accelerate out of vertical maneuvers faster;
- Respond to corrections more quickly;
- Allow more options regarding prop selection and speed of the airplane;
- Maintain vertical speed longer and higher, which is necessary for the turnaround patterns.

Once you've flown a lightweight airplane you'll realize what a joy it is, and how it will improve your flying ability. The following quote from Don Lowe comes from one of his articles about building a lightweight airplane:

"The airplane flies because the wing generates lift by being pulled through the air by an engine/propeller which overcomes the drag of the airplane. The wing must fly at an angle of attack necessary to generate the needed lift required to support the weight of the aircraft. This angle of attack generates what is called induced drag (drag due to lift), which increases as the function of the degree of the angle. The required angle of attack is also influenced by the air speed at which you fly (at a given weight). To sum up: The heavier the plane, the higher the angle of attack and/or flying speed must be to stay in the air, since the steeper the angle the closer you will be to stall speed; so, keep the model light! There is no such thing as a model that is too light. It simply must have sufficient strength to stay together in the air; the wing must be able to handle steady state and maneuvering loads.

"Many modelers make a grave mistake by beefing the model here and there to handle the 'just in case' or hard landing. Any weight that is added compromises the flight performance, makes it more difficult to fly, and increases the probability of a stall/snap roll and crash. Remember, the model is designed to fly, not to crash! It is impossible to add enough beef to the beast to make it a 'survivor'; all you'll be doing is increasing the probability of crashing! A light model is a real joy; it will fly slower, have a less nasty stall, will maneuver more easily and more precisely, will exit a stalled condition much more quickly, will climb, roll and loop better. It has all the virtues of a good airplane. In spite of what is

thought, it will fly better in windy weather conditions. Yes, it is more easily disturbed by gusts, but because of its lightweight, it will damp more quickly, and the net result will be a better flying airplane. So, when you're making choices in the structure and finish of the airplane, keep it light." (*RC Modeler*, June 1990).

We both live and fly in Denver, Colorado, 5,280 feet above sea level. At this altitude the air is much thinner, and flying any type of airplane, whether it be model or full scale, is a real challenge in the summertime. It is not unusual in the middle of the summer to have a mean density altitude of 8,500 to 9,000 feet because of a combination of temperature, humidity and altitude. This poses some interesting problems related to flying model airplanes as compared to sea level flying: our verticals do not go forever, our speeds are faster (to maintain the same flying characteristics), landings are much faster and the wing lift capability is much lower. We cannot vary the design of most standard kits to adapt to high-altitude conditions, so we must move in the other direction: we build the lightest airplane we can. We've become very weight conscious and have developed building techniques that allow us to construct airplanes that weigh seven pounds for 60-size airplanes and eight pounds for 120-size airplanes. After flying 60-size airplanes that weighed eight pounds, and then refined our building techniques so the airplanes now weigh in at a low seven pounds, we can say there is no greater joy than flying a lightweight airplane.

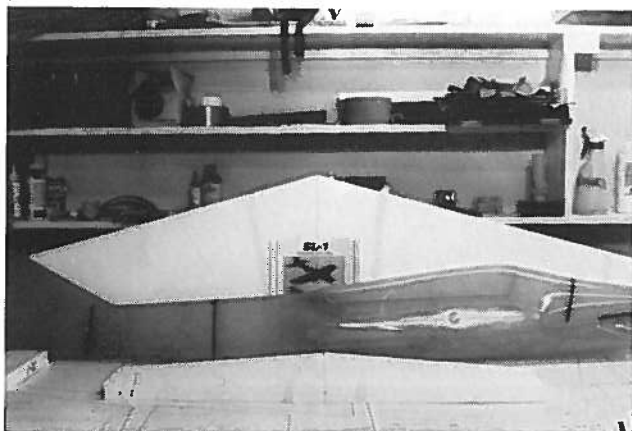
We've attempted to document not only our own techniques, but also the techniques of many others who have constructed lightweight pattern airplanes. If you're one of the many people who have contributed to the techniques in this book, please take pride in knowing that your efforts are now documented for the progress of the hobby. To the first-time builder of pattern airplanes we offer this bit of advice: Stick with it! You, as well as all your predecessors, thought your first pattern airplane could rival any airplane that the national flyers build. This thought, and your

efforts on your first airplane can be applauded. However, when you're half way through and it appears that the RC world aerobatics champion isn't going to come calling for a contract on your airplane, don't get discouraged. Just like your first trainer, you made mistakes, but you learned. Your first pattern airplane will be the same. Read this book, ask lots of questions and don't be afraid to try anything. More than likely, a construction detail that you blindly venture into will be correct and work just fine. Just keep after it and don't get discouraged.

## Chapter 2 THE PATTERN AIRPLANE KIT

### COMPONENTS OF A KIT

Pattern airplane kits are different from most of the model airplane kits you'll find in your local hobby shop. The kits contain only certain key components and are far from a "complete kit" that people are familiar with for sport and trainer planes. Pattern airplanes are generally fabricated from foam cores for the wing and stabilizer, and fiberglass for the fuselage. Other components in the kit include the firewall and landing gear plates cut from 1/4" modeler's plywood and, if a plug-in wing is used, the outboard false ribs cut from 1/8" modeler's plywood and the plug-in tubes for the wings. The remainder of the materials and the components are left up to the builder to choose and purchase.



Basic Kit With Instructions

### SELECTING Balsa WOOD

One of the most important components for the builder building a lightweight airplane is the balsa wood for sheeting the wings, horizontal stabilizer and rudder. Selecting balsa wood is a classic example of what builders go through when constructing the very best airplane: hand-selecting the balsa wood they need from many bundles to arrive at just the right quality and weight to suit the needs; the choice of lightweight balsa for a pattern airplane is one of

the most influential factors in building a lightweight airplane.

Balsa comes in various grades and weights. For a general description of balsa wood and its characteristics, we refer you to the Appendix A. This was prepared by Sig Manufacturing Co., Inc., suppliers of lightweight balsa, and presented with their permission.

### ADDITIONAL MATERIALS NEEDED

The standard pattern airplane kit is not a complete kit and many needed items are left to the builder to purchase. Builders of pattern airplanes are very particular about each and every component installed in their airplane. Taking into account all the combinations of materials and components to choose from, it would be an onerous task on the part of the kit manufacturer to try to accommodate everyone's requests. Therefore a manufacturer's kit contains only the essentials that are specific to that airplane kit. Given the fact that the typical pattern kit contains only the barest essentials, the builder can build with any components he wishes, and arrive at a very heavy airplane, or with care and thought choose not only the components, but also use the proper techniques to build a very light and responsive airplane.

There are a tremendous number of accessories you can choose from when you're ready for final assembly of the airplane. The beginning of the building project comes when it is time to choose the size and type of fuel tank, retracts, main wheels, tail wheel and bracket, linkages to control surfaces, and a myriad other items.

There are many component options you can choose from for your airplane. The retract system is a good example: the way you configure your wing core during construction is directly influenced by the retract system you're going to use. Air retract systems differ from the

mechanical systems in their installation requirements. The type of linkage you use to drive the elevators and rudder need to be considered prior to finishing the airplane. Provisions must be made for their installation. So, before you start building, think through what components you'll be using and build them into the airplane as you go. It is best to purchase all the components you'll be using at the same time you purchase your basic kit. This way everything is handy for measurements and nothing is left to chance. As you're building, you can temporarily fit the components in place to be assured that all the pieces will fit when final assembly is performed.

The following is a list of the additional components and accessories you'll need to construct your airplane. We recommend specific products in the following list. We've also noted specific materials and their manufacturers throughout the book. We are comfortable in recommending what is listed and how to install or assemble it because we've tested and tried each of the materials and techniques in our own airplanes.

In addition to the basic kit, you'll need to purchase the following items:

## 2.1. Balsa wood

**2.1.1. Wing, stab and rudder sheeting:** 25 pieces of *light* 1/16"x3"x36" balsa sheets.

**2.1.1.1. Wing Balsa sheeting:** enough 1/16" sheeting glued together to result in a width of approximately 36" and lengths of approximately 48". This can be accomplished by edge gluing 16 pieces of 36" long by 3" wide sheets together.

**2.1.1.2 Stab Balsa Sheetting:** enough 1/16" sheeting glued together to result in a width of approximately 16" and a length of approximately 27". This can be accomplished by edge gluing six pieces of 36" long by 3" wide sheets together then cutting the sheet in half.

**2.1.1.3 Rudder Balsa Sheetting:** enough 1/16" sheeting glued together to result in a width of approximately 8" and a length of approximately 26". This can be accomplished by edge gluing three pieces of 36" long by 3" wide sheets together.

**2.1.2. Leading edge:** two pieces of light 1/4"x3/4"x36" balsa sticks. This material can be cut from 1/4"x3"x36" balsa sheets.

**2.1.3. Trailing edge:** three pieces of light 1/4"x1/4"x36" balsa sticks. This material can be cut from 1/4"x3"x36" balsa sheets.

**2.1.4. Wing and stab root and false ribs:** one piece of 1/8"x12"x24" lite-ply.

**2.2. CA Glue,** one ounce

**2.3. Epoxy-Slow cure for sheeting:** Zpoxy finishing resin is thin and easy to use.

**2.4. Epoxy-Fast cure for miscellaneous needs:** use your favorite brand.

**2.5. X-Acto Blades.**

**2.6. Elevator push rod:** Dave Brown fiberglass pushrod system. Or if you really want to go to extremes, there are now small diameter carbon fiber push rods available. These rods are extremely light and strong.

**2.7. Plastic Covering Material:** either Ultracoat or Monokote.

**2.8. Rudder pull-pull cables and ends:** use "control line leadout" cables.

**2.9. Rudder pull-pull hardware:** fabricate it from 4-40 rods, two nuts, brass tube, aileron control horns, quick links and threaded couplings.

**2.10. Engine soft mount or hard mount:** whichever you choose for hard mount. For soft mount use the Sullivan mount for 2-cycle systems. For

4-cycle airplanes there are many, but we like Merle Hyde's mount. However, the Aero Sport and Gator mounts are also widely used.

**2.11. Fuel tank:** size the fuel tank to your particular requirements; a 12-ounce tank is sufficient for the current FAI or AMA pattern. For sport or practice flying you may want to use a larger tank.

**2.12. Threaded rods for elevator, throttle, aileron and rudder linkage.**

**2.13. Tuned pipe support:** either Dave Brown or custom made.

**2.14. Tail wheel bracket and wheel:** Dubro 60-size works well with a 1" tail wheel.

**2.15. Main gear retracts (mechanical):** Supra gear is recommended. Imitations don't last very long.

**2.16. Foam rubber:** Carl Goldberg works well.

**2.17. Hinges:** Hayes for epoxy adhesive or the instant hinges for CA (be very careful when installing the instant hinges; see the text for details).

**2.18. Clevis:** Hayes work well. They have a metal pin and a plastic body. This is the best of both worlds. The metal pin doesn't wear and the plastic body screwed on the threaded rod ends doesn't strip out.

**2.19. Fuel tubing:** the choice is yours. We prefer Prather tubing because it has a slightly thicker wall.

**2.20. Adjustable axles and wheel collars for the retract landing gear:** if you just bend the landing gear to accommodate the wheel, you run the risk of having your wheel bind on the bend. If you use the Goldberg adjustable axles (or similar lightweight adjustable axles) not only does it eliminate the possibility of binding but also

allows for minute adjustments if the airplane is not tracking well on takeoff or landings.

**2.21. Main landing gear wheels:** Dave Brown lightweight sponge wheels are very good. They look like they wouldn't last more than a few takeoffs and landings, yet they are durable, lightweight and the rubber will not roll off the rims.

**2.22. EZ connectors:** these connectors are used for attaching the mechanical retract wires to the retract wheel servo. The hex head connectors are easy to use and install.

**2.23. Hex head bolts:** 4-40x1/2" for belly pan and canopy.

**2.24. Hex head screws:** #4x1/2" for landing gear.

**2.25. Bulkhead fittings for fuel line:** Foremost bulkhead fittings are easy to install and work well.

**2.26. Fuel Buttons:** handy little devices for fueling your airplane (see text for pictures and description).

## ADDITIONAL TOOLS NEEDED

There are very few specialty tools necessary to construct a pattern airplane. In our earlier years the only power tools we used were an electric drill and a Dremmel jig saw. But as we progressed we found the need for a few specialty tools, which include the following:

### 2.27. Band saw

The band saw is used for cutting the elevators from the stabs and the ailerons from the wing panels. It works much better than a jig saw because it cuts a much straighter and smoother line. This is important because the smoother the faces of the elevators and ailerons are, the less likely that warpage will occur.

### 2.28. Incidence meter

This meter is used to measure the incidence of the wing and stabilizer panels. The incidence meters on the market today are tolerable; if you're building your first pattern airplane, we highly recommend purchasing one. We built our own incidence meter from the components of the Robart Incidence Meters and a "Smart Level" builder's level. However, the "Smart Level" is no longer available. If you're an experienced builder, we recommend obtaining a Macklanburg-Duncan "Samrttool"™. This level measures to the tenth's of degrees. Combined with an alignment jig, the level becomes a very effective incidence meter. After having built and used an incidence meter that measures to the tenth of a degree, we can say that the frustration level and amount of time spent on the final alignment of our airplanes has decreased appreciably.

#### 2.29. Builder's level

The Macklanburg-Duncan "Samrttool"™ is an excellent level that gives a digital read-out in tenths of degrees. A digital read-out eliminates the need to attempt to center the bubble of a common builder's level between the two marks. Since the alignment of your airplane is critical, it is important that you have the best level and incidence meter you can get.

#### 2.30. Gram scale

Probably one of the most important tools or instruments we've purchased for constructing lightweight pattern airplanes is a good gram scale. Without a very accurate scale to weigh the components, you're only guessing at weights and knowing the weight of airplane components is absolutely necessary when constructing a lightweight plane. Knowing what each of your balsa sheets weighs allows you to install only the light pieces and leave the others for some other project that might not demand the weight tolerances of your pattern airplane. Knowing from the start of construction what the components weigh will make you "weight-

conscious." (Before purchasing gram scales we were building 60-size airplanes that weighed just over eight pounds.) We finally purchased very accurate gram scales, but they were expensive at \$115.! After purchasing the scale, we weighed everything! We weighed all the components in our existing airplane: balsa sheets and sticks, engines, propellers, spinners, everything you could imagine. We compared the weights of these items against the recorded weights of airplanes weighing 7 pounds, 4 ounces. We found that there was not just a single component that added all the weight to our airplanes, but the accumulation of a gram here and there. A lightning bolt hit us. We realized that the way to decrease the weight of an airplane was to watch everything that went into the airplane. We then started our next project. Weighing this and that, we asked ourselves if we really needed every component. We kept track of exactly what each one weighed during construction. When we were done, we weighed the complete airplane. Lo and behold, it weighed 7 pounds, 4 ounces; we'd managed to eliminate 12 ounces from the same design airplane! *We can't overstate the importance of weighing everything that goes into your plane.* Now we have records that we can refer to that allow us to predict the weight of the final product after we have sheeted the wings. We also cannot overstate the importance of purchasing a small, accurate gram scale to perform your weighing.

To the first-time builder this might seem ludicrous, but if you start thinking in grams instead of ounces you'll be in the right frame of mind to construct lightweight airplanes. You'll begin weighing everything and also questioning how to lighten components without compromising the strength.

## Chapter 3 FUSELAGE

### GENERAL INFORMATION

The information contained in this chapter pertains to fiberglass fuselages. Specifically, we have outlined the construction techniques for the SL-1. The SL-1 instructions relate to a number of airplane fuselages available today.

### FUSELAGE CONSTRUCTION

The fuselage, canopy and belly pan are constructed of fiberglass cloth and epoxy resin placed in a mold and cured. First the molds are sprayed with a gelcoat. This gelcoat is the actual finish of the outside of the airplane. It's not very thick and doesn't add to the structural integrity of the part. Its function is to give the components a smooth finish. Next, fiberglass cloth is laid in the mold with reinforcements laid on top of the fiberglass cloth. This cloth comes in weights and is generally designated as "ounces per square yard" of fabric. On the average, most kit manufacturers use a four-to-five ounces-per-yard cloth. This gives the component the necessary strength, without compromising weight. Once the cloth and reinforcements are in place, the cloth is saturated with epoxy resin. The resin is applied as thinly as possible to reduce the amount of material in the component and to subsequently keep the weight as light as possible. The "lay-up," as it is called, is allowed to cure for a prescribed time. Then both halves of the fuselage, belly pan and canopy, are joined together by a thin strip of fiberglass cloth and resin. This process produces the jagged ridge at the seam that is present on most fiberglass fuselages and belly pans.

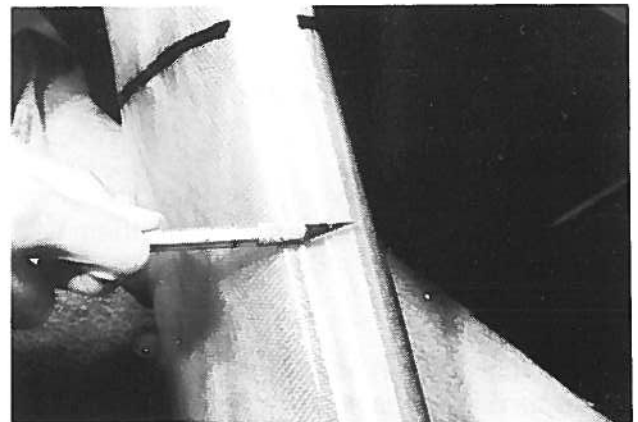
### FUSELAGE PREPARATION

After you've opened your new kit, removed all the packing material, examined all the components for damage and checked to make sure you've received all the pieces, you're ready to get started.

The first step is to wash the fiberglass components thoroughly with alcohol. This is done to remove any of the release agents that might be present on the outside of the fuselage. Give it a good scrub both inside and out to be assured that the entire release agent has been removed. Do not use soap and water. The soap will leave a residue on the surface that will complicate the building and finishing process. Once washed thoroughly, dry it (either in the sun or with a towel). With the fuselage clean you're ready for the next step.

Most fiberglass fuselages have a ragged joint or seam that needs to be smoothed down and filled with appropriate filler. Follow the steps listed below to remove the seam on the fuselage, belly pan and canopy and cover the seam so it is not apparent when painted.

3.1. With the back of an X-Acto knife blade, scrape the excess fiberglass resin down to the fuselage. This step will not make the seam smooth; it is done to eliminate the excess material.



Removing Excess Material From Fuselage Seam

3.2. Using 200-grit wet/dry sandpaper mounted on a sponge block, sand the seam. The proper technique is not to sand parallel to or with the seam, but to cross the seam at a 45° angle. Sand so a flat spot is not formed at the seam. In addition, be careful not to remove the gel coat

from the surrounding areas. The purpose of the gel coat is to give the fiberglass parts a smooth finish. If you sand too much, pinholes will form, which will cause problems when you finish the airplane.

**3.3.** Apply automotive body filler to the seam. You need not apply big clumps of the stuff. All you want to do is fill in any depressions at the seam. The body filler we like is Evercoat glazing putty. We find it easy to use and fairly lightweight in comparison to other body fillers. You can purchase it at your local auto body repair store.



Applying Body Filler To Prepared Fuselage Seam

**3.4.** Sand off the excess body filler using the same sanding technique as explained or discussed previously.

**3.5.** Inspect the fuselage and all other fiberglass parts for pinholes. If you find some, fill them with polyester body filler or Prather pinhole filler and sand until smooth.

**3.6. (OPTION)** As an option prior to performing a lot of work on the fuselage prime it and all fiberglass parts and inspect for pinholes. We find that once a fiberglass part is primed the pinholes become very apparent. If the fuselage is full of pinholes, you can contact the manufacturer and obtain another. However, if you have installed the firewall, horizontal stabilizer, canopy, belly pan and wings, it's very difficult to send that fuselage back for another. To prime the fuselage, first buff it with a Scotch

Brite Pad; this removes the gloss from the gel coat, but does not remove more than necessary.

**3.7. (OPTION)** Mix primer and either brush or spray it on. We mix two parts of K & B primer and then add micro balloons until it has a slurry consistency. We then paint it on with a brush. If we see areas with very small pinholes, we brush a little more on. Don't worry about the runs or drips. All the excess will be sanded off before the final coats of paint are applied.

**3.8. (OPTION)** Once the primer has dried, sand it down and inspect for pinholes. If all pinholes have been filled in, you can continue. If there are some left, apply more polyester body filler. If there are a lot of holes, contact the manufacturer and obtain a replacement. Remember, body filler does weigh something, and the more you put on, the heavier the plane will be. Try to keep the application of the body filler to a minimum.

**3.9.** The SL-1 comes with the reference lines molded into the sides of the fuselage for the wings and horizontal stabilizers. If the reference lines are not molded into the fuselage it will be necessary to establish these reference lines. Refer to instruction in Chapter 6 to establish these lines.

## **FIREWALL AND ENGINE INSTALLATION (SOFT MOUNT)**

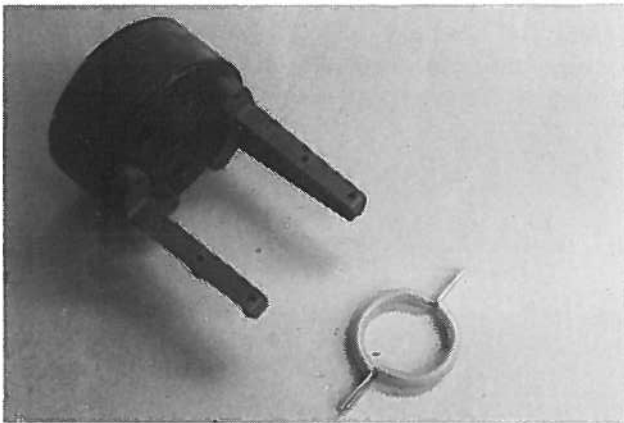
Except for the airplane meeting terra firma at a high speed, one of the most deteriorating forces acting on a model airplane is the transmission of engine vibration into the airframe. This vibration leads to the premature failure of the airframe, batteries, servos and receivers. To minimize this problem a "soft mount" should be used to mount the engine to the firewall of the airframe.

The idea behind soft mounts is to minimize the amount of engine vibration being transmitted into the airframe. Soft mounting does not affect the alignment of the engine. Watch a soft mounted engine at idle. It moves around radically (shakes). However, once the engine is

throttled up, it remains steady in one position. In that one position the engine is properly aligned with the airframe, but the engine vibration is not transmitted to the airframe. With a solid mounted engine all this vibration is being transmitted into the airframe. The absence of engine vibration being transmitted into the airframe results in a quieter airplane and radio components that will last much longer.

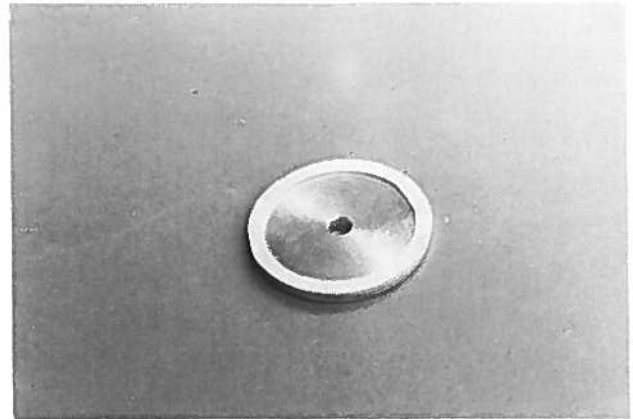
A soft mounted engine does not require more spinner clearance than a hard mounted engine. We have soft mounted many engines with just 1/16" clearance between the back of the spinner and the fuselage and have had no problem with the engine or spinner contacting the fuselage.

The installation of a soft mount takes a little more time than a hard mount, but the benefits of longer radio and airframe life is worth the time.



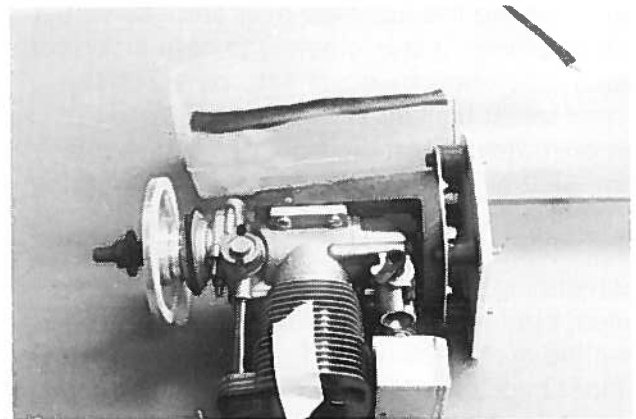
Hyde Soft-Mount For the YS120 Engine

**3.10.** Make a spacer from 1/16" balsa sheet and tack glue the spacer to the back of the spinner back plate. The spacer should be the same diameter as the spinner.



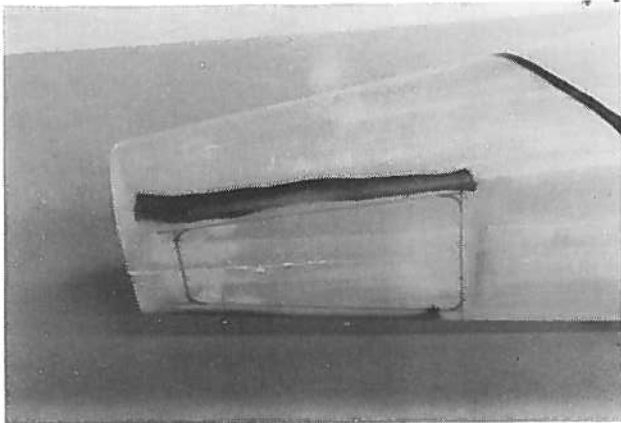
Spacer Ring Glued To Spinner Backplate

**3.11.** Most kits do not have an area of the fuselage removed for the engine compartment. To identify this area, install the soft mount on the engine, install the spinner backplate with the 1/16" spacer to the engine. Take the assembly and place it next to the fuselage. Place the spinner backed with the 1/16" balsa wood against the fuselage. Mark the fuselage at the back of the motor mount. These marks show roughly where the front of the firewall will be installed.



Locating Firewall W/ Engine & Mount

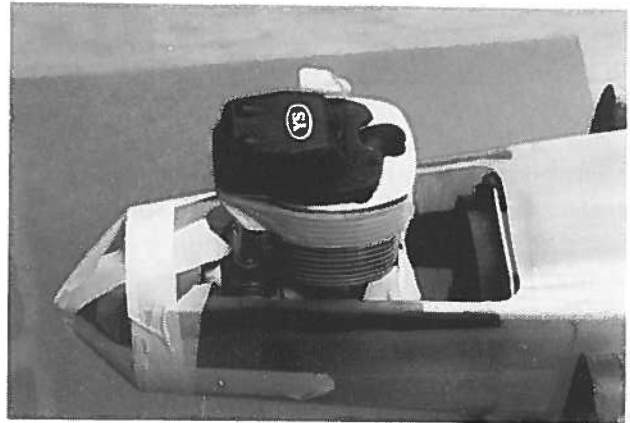
**3.12.** Mark the bottom of the fuselage where the engine will protrude when final assembly is complete. Be conservative; at this time don't remove a lot of material, just enough to initially fit the engine into the fuselage.



Area To Be Removed For Engine Installation

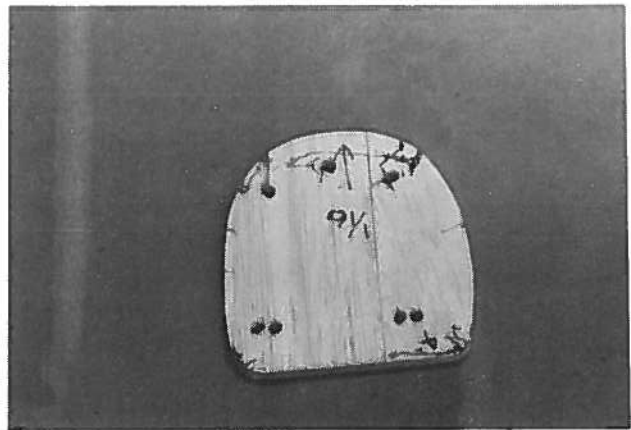
**3.13.** Sand and clean the inside of the fuselage at the area where the firewall will be attached.

**3.14.** Slide the engine into the engine compartment and install the motor mount. Install the prop and spinner backplate on the engine while the engine is in the engine compartment (use the hub of an old prop). Hold the fuselage upright and align the spinner backplate with the nose ring. Tack-glue the spinner backplate balsa spacer to the fuselage nose ring area. The assembly should be fastened firmly enough to permit turning the fuselage over and standing it on the spinner. It is interesting to note that most pattern fiberglass fuselage kits come with the correct thrust built into the fuselage. To demonstrate, look at the front of the fuselage from the top. You will note that the "spinner ring" on the fuselage is angled to the right. Utilize this built-in feature. It's a good place to start. During the trimming phase of flying the thrust can be varied, but for now let's build the airplane with what the manufacturer suggests. By placing the spinner back plate directly on the front of the fuselage and tack gluing it to secure it in position we automatically build in the suggested right and down thrust (see note in step 3.10).



Engine/Mount Temporarily Installed

**3.15.** Cut a balsa template of the firewall. Trial-fit the template into the fuselage by dropping it on the rubber isolation mounts. It should lie easily on the mounts; there should be a small gap between the fuselage and the template. If the template, or ultimately the firewall, presses against the fuselage during the assembly process, improper final alignment will result.



Firewall Template

**3.16.** While the firewall is loose and still accessible, you may wish to locate and drill the holes for the throttle cable and the fuel lines.

**3.17.** Once you're satisfied with the fit of the template inside the fuselage, re-check the spinner alignment and rotate the engine so that the glow plug will be in the center of the engine cowl and then secure the engine with masking tape.

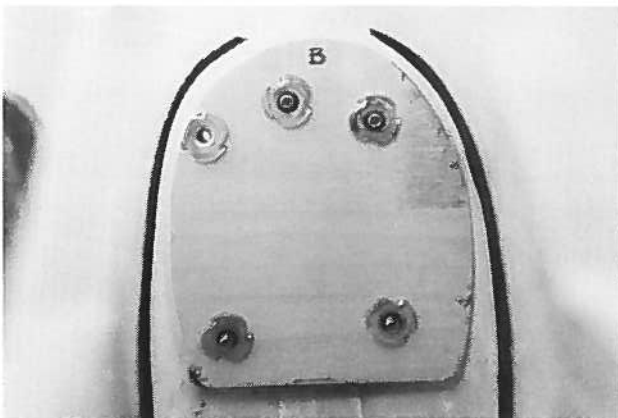
**3.18.** Using the balsa template, cut a firewall from the appropriate material.

**3.19** Reach inside the fuselage and place two or three drops of thick CA glue on the back of the motor mount. Slide the firewall inside the fuselage and place it against the back of the motor mount.

**3.20** Once the glue has cured and the firewall is tack glued securely to the back of the motor mount, gently remove the prop from the engine. Gently pry the spinner with the balsa spacer free from the fuselage. Next remove the engine from the motor mount. Be very careful performing this dis-assembly process. Avoid breaking the temporary bond between the firewall and the motor mount. Remove the motor mount and firewall combination from the inside of the fuselage.

**3.21** With the motor mount still fastened to the firewall, drill holes through the firewall using the motor mount holes as a template. Break the temporary bond between the motor mount and the firewall and install the blind nuts.

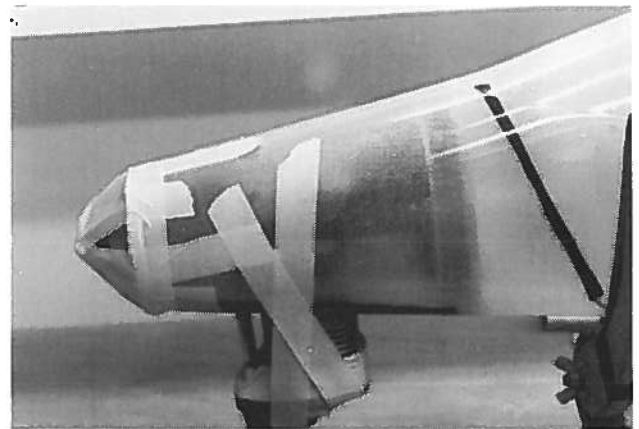
**3.22** Again, Insert the engine into the fuselage. Slide the motor mount into the airplane and bolt the firewall to the motor mount. Screw the engine to the motor mount. Assemble the spinner and prop assembly. Align the spinner to the fuselage again and tack-glue it in place.



Necessary Gap Between Firewall And Fuselage Side

If all is assembled correctly, there should be a small gap between the firewall and the fuselage all the way around the firewall. The thrust of the engine (which is built into the spinner ring of the fuselage) depends upon how the firewall fits inside the fuselage with the engine installed. The firewall must fit closely enough so that there isn't a large gap between the firewall and the fuselage, but shouldn't be in contact with the fuselage. To check the clearance, slide a piece of paper between the fuselage and the firewall. Check the clearance around the circumference of the firewall. If it binds anywhere, reach into the fuselage and mark the spot on the back of the firewall. Disassemble all the components, remove the excess material from the firewall and reassemble.

Once a small gap has been established around the circumference of the firewall, epoxy the firewall to the fuselage with a mixture of thirty-minute epoxy and microballoons from inside the fuselage. The microballoons thicken the epoxy so it can be formed into a nice fillet at the joint between the fuselage and the firewall.



Firewall Tack Glued In Place

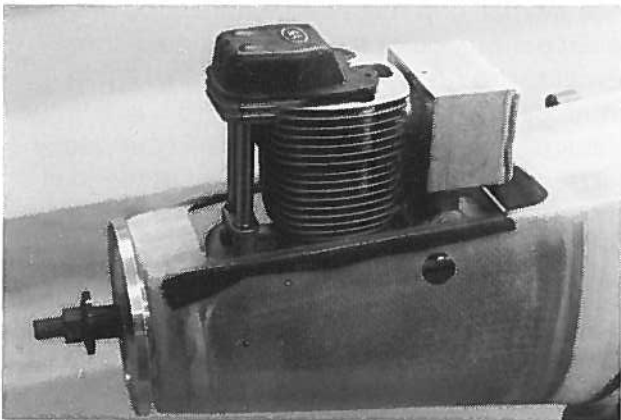
**3.23.** Once the epoxy mixture has cured, remove the engine, motor mount and spinner assembly.

The firewall may now be permanently glued in place with more thirty-minute epoxy, microballoons and glass cloth. When you first apply the epoxy make sure you push it into the gap between the fuselage and the firewall. You'll know when you've filled the gap, because a dark

line will appear on the outside of the fuselage where the epoxy has filled the gap. Then you can apply a thin strip of fiberglass cloth on both the firewall and the fiberglass fuselage. Cover this fiberglass with epoxy and microballoons and form a smooth fillet inside the engine compartment between the firewall and fuselage sides.

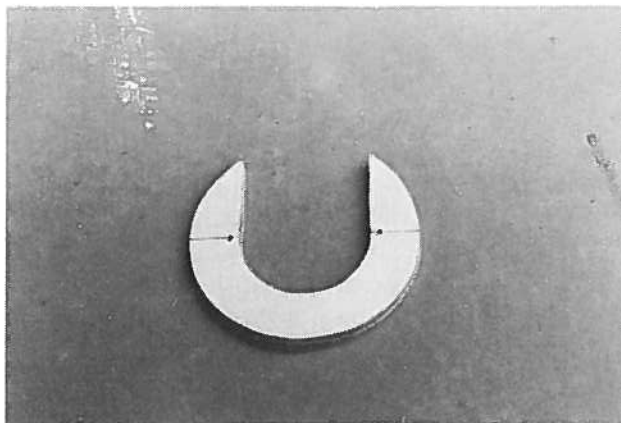
Once the epoxy is applied and the engine is aligned properly, leave it alone and let the epoxy cure for an evening.

Also, use only epoxy in the engine compartment of any airplane. Epoxy does not break down under the influence of nitro methane that is found in airplane fuels. If you do use CA or other adhesives, cover them with a coat of epoxy.



Checking Clearance With Firewall Installed

**3.24.** Cut the front retainer ring holder from some light-ply material.



Front Retaining Ring Holder

**3.25.** With the engine still in the airplane and the firewall epoxy completely cured, remove the engine tape and remove the spinner and prop hub. Slide the retainer ring holder into the fuselage (you might have to remove the engine to do this). Slide the retainer ring over the front of the engine and fasten it to the retainer ring holder. Install the spinner and prop hub and check for alignment. With the engine properly aligned, the retainer ring and retainer ring holder in place (again with a small gap between the holder and the fuselage), epoxy the retainer ring holder to the fuselage. Do this at a couple of spots with some five-minute epoxy. Wait for the epoxy to cure, then carefully unbolt the engine from the mount and remove the engine, spinner and motor mount from the fuselage. Once again, using some epoxy mixed with microballoons, form a nice fillet of epoxy at the joint of the fuselage and the retaining ring holder.

**3.26.** Coat exposed areas of the firewall in the engine compartment with a thin coat of slow-cure epoxy. NOTE: you can reduce the viscosity of slow cure epoxy and also increase the set-up time by mixing in a small amount of alcohol.



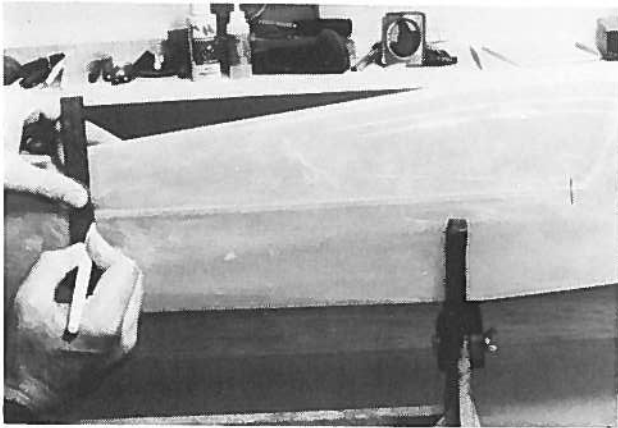
Installed Front Retainer Ring And Firewall

## CANOPY INSTALLATION

**3.27.** Place the canopy on the fuselage and check for high spots of resin, flashing or fiberglass that prevent the canopy from fitting properly on the fuselage. If there are resin spots or flashing interfering with the fit, remove them with an X-Acto knife and sandpaper or file.

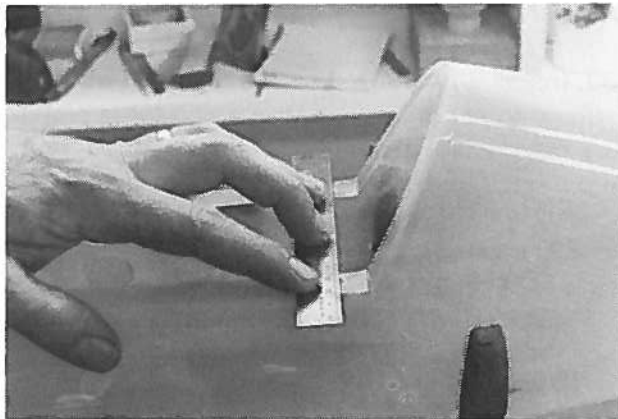
**3.28.** Using masking tape, secure the canopy to the fuselage in the final installed position.

**3.29.** Make marks with a felt tip pen on the fuselage and canopy where the guides will be located. It is best to align these guides at the same spot on each side of the canopy.



Marking Location Of Retainers

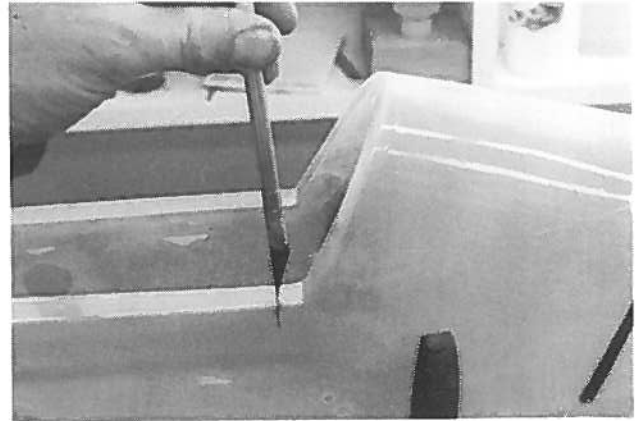
**3.30.** Remove the tape and the canopy. Using a straight edge, draw a line on each supporting flange of the canopy at the points opposite each other on the canopy. Repeat this for the fuselage.



Transferring Marks To Inside Flanges

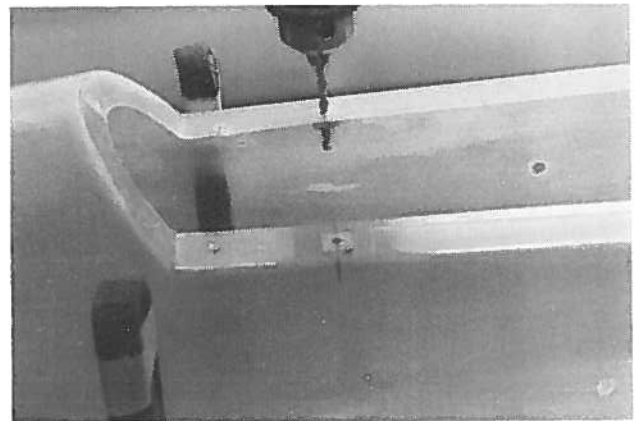
**3.31.** Measure in from the edge of the canopy and the edge of the fuselage approximately 1/8" to 3/16" and make a mark on the line that connects the opposite marks on the canopy and the fuselage.

**3.32.** Drill a 1/8" hole at each of the marks. Start these holes by using the tip of an X-Acto knife and bore a small impression in the fiberglass.



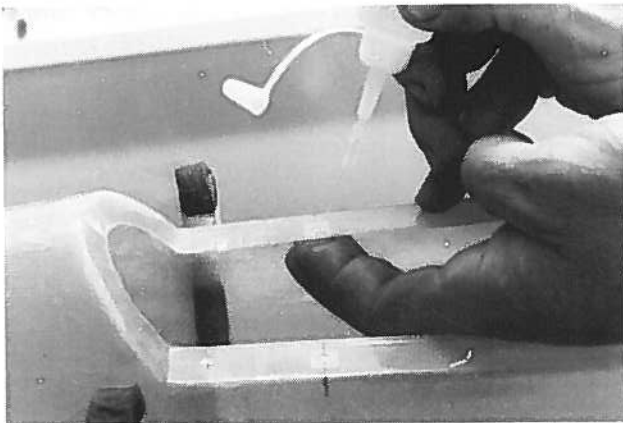
Starting A Hole With An X-Acto Knife

**3.33.** Place a 1/16" drill bit tip in the impression and slowly drill a hole. Then chase the hole with a 3/32" drill bit and then a 1/8" drill bit. Following this procedure will ensure the hole will stay reasonably centered. If you start with the 1/8" drill bit, you run the risk of the drill bit moving from center before the hole is actually drilled.



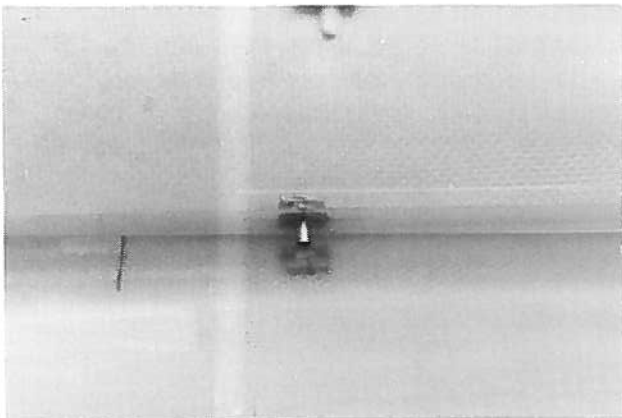
Drilling Holes For Retainers

**3.34.** When you're finished drilling the holes, install 1/8" thick by 1/4" square pieces of plywood on the backside of each guide hole. Glue these in place with either CA adhesive or fast-cure epoxy. When the adhesive or epoxy has thoroughly set, drill a 1/8" hole through the back-up pieces of plywood, using the hole in the fiberglass as a guide.



Installing Back-Up Plates For Retainers

**3.35.** You can use the Violet hatch pins to align your hatches, or use pop rivets. Either one will work, but the pop rivets are less expensive and a bit lighter. Rough up the pop rivets so the adhesive will hold. Secure the pop rivet to the plywood using either epoxy or CA adhesive.



Pop Rivets Installed For Retainers

**3.36.** Trial-fit the canopy to the fuselage by inserting the pop rivets into the respective holes in the fuselage. Enlarge the holes in the fuselage to accept the 1/8" pop rivets if required.



Trial Fitting Canopy To Fuselage

**3.37.** Install a canopy hold-down at the back of the canopy. We prefer the Violet hatch latch. This little device is lightweight and easy to install. It allows quick and easy removal and is very positive. We haven't had a canopy depart from the airplane in flight since we started using this hatch latch.

**3.38.** Cut a slot in the canopy to accommodate the slide. Drill a hole in the fiberglass flange of the canopy for the pin to protrude from the canopy into the fuselage. Install the hatch latch by either epoxy or CA adhesive.

**3.39.** Install a back-up piece of plywood on the fuselage to accommodate the hatch latch pin. To mark the position on the fuselage plywood, pull the pin back to the retract position, install the canopy on the fuselage and then press the pin into the back-up plate on the fuselage to leave an impression. Remove the canopy and drill the back-up plywood plate to accept the canopy hatch latch pin.

**3.40.** Reinstall the canopy and check the fit. Enlarge the holes for the guides as necessary to allow for a proper fit.

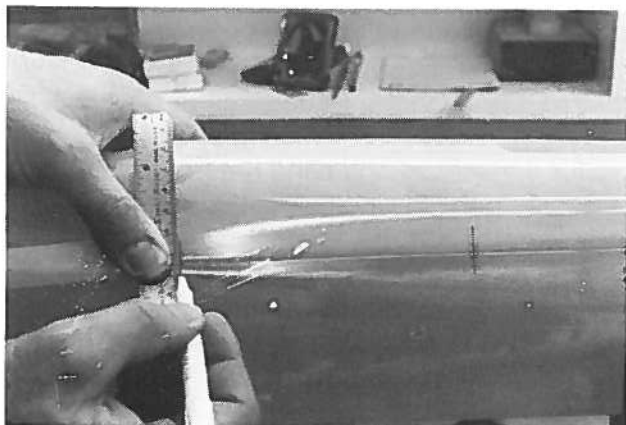
**3.41.** The canopy should be stiffened by adding two 1/4"x1/4" balsa cross braces on the bottom.

## BELLY PAN INSTALLATION

**3.42.** Fit the belly pan to the fuselage and check for flashing, high spots of resin or fiberglass that prevent the belly pan from fitting properly in its place. If there are resin spots or flashing interfering with the fit, remove them with an X-Acto knife and sandpaper or file.

**3.43.** Using masking tape, secure the belly pan to the fuselage in the final installed position.

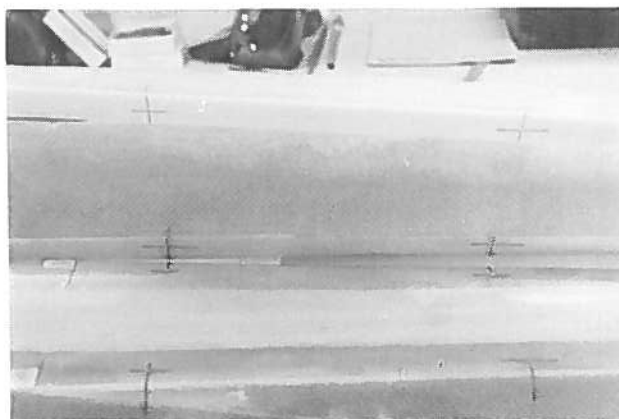
**3.44.** Make marks with a felt tip pen on the fuselage and belly pan where the guides will be located. It is best to align these guides at the same spot on each side of the belly pan.



Marking Locations Of Retainers

**3.45.** Remove the tape and belly pan. Using a straight edge, draw a line on each supporting flange of the belly pan at the points opposite each other on the belly pan. Repeat this for the fuselage also.

**3.46.** Measure in from the edge of the belly pan and the edge of the fuselage approximately  $\frac{1}{8}$ " to  $\frac{3}{16}$ " and make a mark on the line that connects the opposite marks on the belly pan and the fuselage.

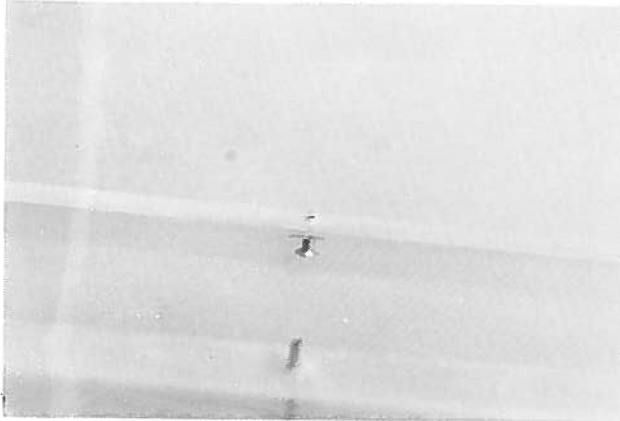


Transferring Marks To Flanges

**3.47.** Drill a  $\frac{1}{8}$ " hole at each of the marks. Start these holes by using the tip of an X-Acto knife and bore a small impression in the fiberglass. Place a  $\frac{1}{16}$ " drill bit tip in the impression and slowly drill a hole. Then chase the hole with a  $\frac{3}{32}$ " drill bit and then a  $\frac{1}{8}$ " drill bit. Following this procedure will ensure that the hole will stay reasonably centered. If you start with the  $\frac{1}{8}$ " drill bit, you run the risk of the drill bit moving from the center before the hole is actually drilled (see photos in steps 3.32 and 3.33).

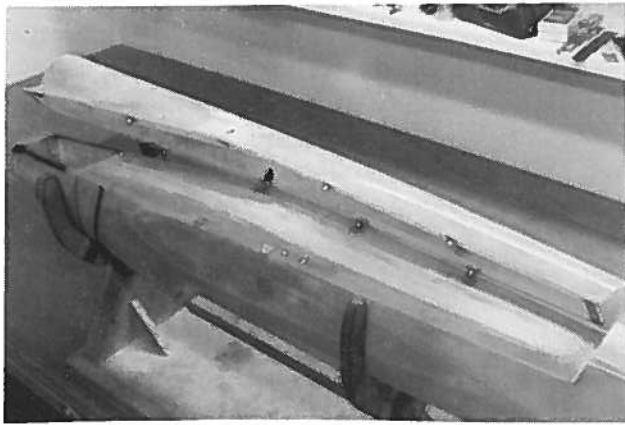
**3.48.** When you're finished drilling the holes, install  $\frac{1}{8}$ " thick by  $\frac{1}{4}$ " square pieces of plywood on the backside of each guide hole. Glue these in place with fast-cure epoxy. When the adhesive or epoxy has thoroughly set, drill a  $\frac{1}{8}$ " hole through the back-up pieces of plywood, using the hole in the fiberglass as a guide (see photo in step 3.34).

**3.49.** Insert pop rivets into the holes backed up with plywood, in the belly pan. Secure the pop rivets to the plywood using either epoxy or CA adhesive.



Pop Rivets Installed For Retainers

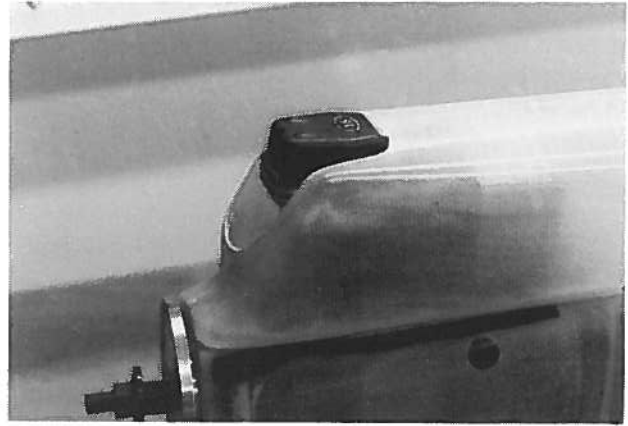
**3.50.** Trial-fit the belly pan to the fuselage by inserting the pop rivets into the respective holes in the fuselage. Enlarge the holes in the fuselage to accept the pop rivets, if required.



Trial Fitting Belly Pan To Fuselage

**3.51.** Remove the belly pan and install the engine. To allow the belly pan to fit in its proper position with the engine installed, place the belly pan over the engine and mark the areas of fiberglass that need to be removed. Remove the fiberglass for the cooling air intake into the front of the belly pan and the cylinder head. Be conservative and go slowly. Continue to fit the belly pan in its proper place and mark the areas on the fiberglass that need to be removed. Remove the fiberglass and trial-fit the belly pan again. Continue this process until the belly pan fits over the engine with enough clearance to accommodate the movement of the engine while properly fitting on the fuselage (the engine will

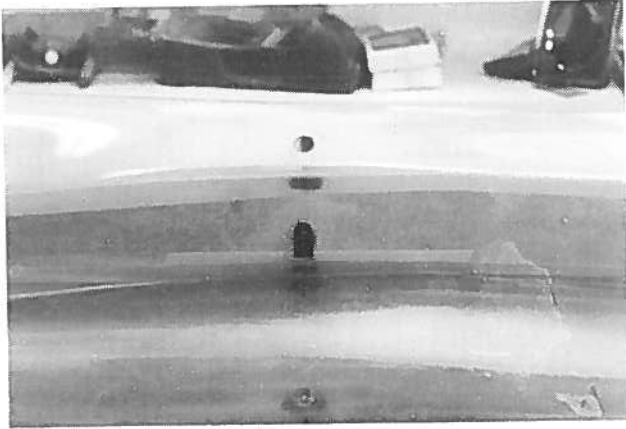
shake as much as 1/2" each direction at idle on a soft mount, so give it plenty of room).



Belly Pan Cut Around Engine

**3.52.** To secure the belly pan to the fuselage and also allow removal, CA glue or epoxy 1/8" plywood plates on the front, sides and back of the belly pan and on the fuselage. Drill a pilot hole for a 4-40 bolt and blind nut at the front of the engine only. Install the blind nut and bolt at this location. Then drill another pilot hole on one of the sides. Remove the belly pan and install a blind nut in the fuselage and drill out the hole in the belly pan to accommodate a 4-40 bolt. Reinstall the belly pan and check the fit. Enlarge holes for the guides as necessary to allow for a proper fit. Repeat this step for the opposite side and then the back. The idea is to anchor the belly pan, then drill a new hole. Doing this assures you a positive fit of all bolts without having to enlarge any holes.

We indulge in a nice detail at all the bolt locations. After the bolts are located, cut small pieces of fiberglass arrow shaft. Enlarge the holes in the belly pan *above* the bolts to accept the arrow shaft pieces (make sure the holes are centered over the bolt). Drop the arrow shaft piece through the hole and butt it against the 1/8" plate used for the bolt back-up. Once you're satisfied with the fit, glue the arrow shaft to the 1/8" plate at the bottom and the fiberglass belly pan at the top. Now sand down the top of the arrow shaft piece on the outside of the belly pan to match the contour of the area. Now you have a nice "chase" for your bolt.



Belly Pan Bolt Enclosures

## Chapter 4 RUDDER

### RUDDER CONSTRUCTION

Ah ... the much maligned rudder. Most builders will build the rudder last; however, we believe the rudder should be built first. The rudder is a great place to start developing your technique for sheeting and honeycombing. There is not much in a rudder, so if you should happen to make a *big* mistake, toss it away and frame up another. However, do *not* try that with a wing panel. That is when it gets costly! In addition, the rudder is a great trial piece if you want to experiment with some advanced building techniques like honeycombing.

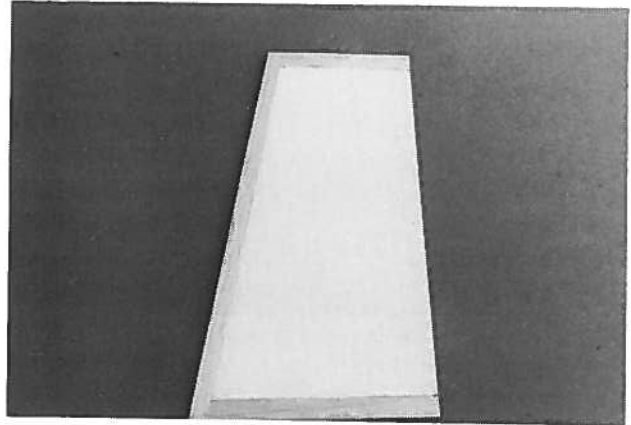
The beginning builder should start with the rudder first and finish it completely before starting on the horizontal stab halves. Completely finish the stab halves and then progress to the wing panels. If you follow this sequence, you'll develop technique expertise and by the time you get to the wing panels, you'll have enough experience to be successful.

Everyone looks at each other's wing panels for good building expertise, but when was the last time you admired someone's rudder? Get the idea?

Before starting the rudder, read and thoroughly understand the sections on building wing panels. Then come back to this section and build your rudder.

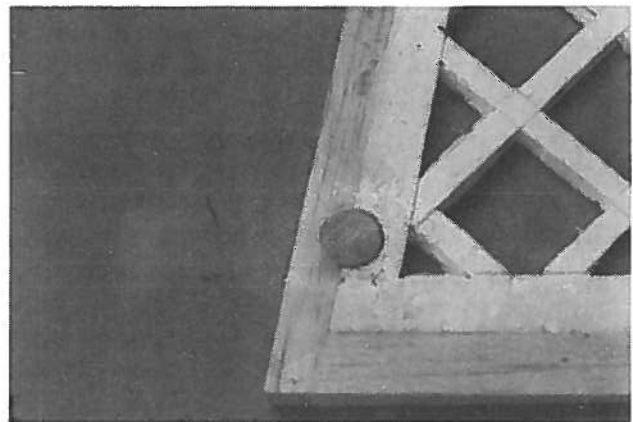
**4.1.** Cut the required-size balsa sticks for the hinge post, bottom and top rib. Cut the bottom rib with enough excess to allow for shaping. The bottom rib will be shaped to blend into the fuselage.

**4.2.** Glue the bottom and top rib and hinge post to the foam core.



Faced Rudder

**4.3.** Drill a hole for the 3/8" dowel with a piece of sharpened brass tube. Cut a 3/8" dowel flush with the surface by first sliding it into the hole in the foam core and then tracing the outline of the adjacent foam area on the dowel. Cut the hardwood dowel to the proper length and glue it in place. Sand the hardwood dowel flush with the adjacent foam. Be careful and take your time. We use a Dremmel tool with a sanding attachment and use extreme care.



Dowel Reinforcing For Control Horn

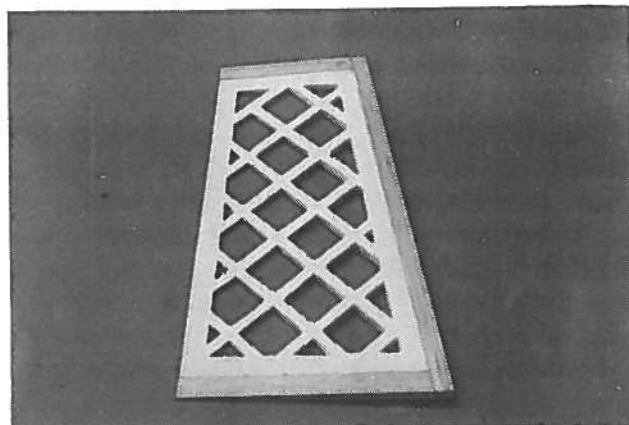
**4.4.** Sheet the rudder with 1/16" balsa. Read the instructions on sheeting in the "Wing & Stabilizer Sheeting" section and paragraph 4.8 below, if you wish to honeycomb your rudder, before proceeding with this step.

**4.5.** Using an X-Acto knife or a razor blade, slice 1/4" off the rudder core trailing edge. Glue a piece of 1/4" square balsa on the trailing edge using Tite-bond or epoxy. When dry, shape the trailing edge using a razor plane and sanding block. Bevel the leading edge to allow at least 45° travel in each direction.

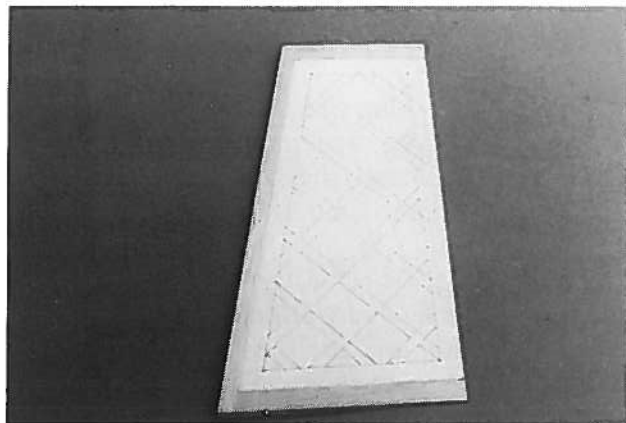
**4.6.** Drill the dowel for a control horn bolt size of your choice.

**4.7.** Cut slots for hinges in the fuselage rudder post and rudder hinge post. Put the rudder assembly aside for now. The tail post and rudder will not be installed onto the fuselage until the horizontal stabilizer has been installed.

**4.8.** If you wish to experiment with honeycombing, the rudder is a good place to start. Before you sheet the core with the 1/16" balsa sheets, draw a "honeycomb" pattern on the core. We leave at least a 1/2" border around the edges; our rudder holes are then about 1" square with 1/4" strips of foam.



Honeycomb Void Area Removed From Rudder



Honeycomb Pattern Drawn On Rudder Core

**4.9.** Cut out the "holes" with a sharp X-Acto knife. Apply epoxy to only the foam area, with either a monojet syringe or an acid brush. For a further explanation on how to apply the epoxy refer to the sheeting section in the wing/stab section.

## Chapter 5 WING AND STABILIZER

### GENERAL WING AND STAB CONSTRUCTION

Before you get involved in the construction of the wing and stabilizer, it is important to first realize how each component works and why manufacturers use the materials they do for these components.

The wing and stab are the two most critical components of the aircraft. They define the flying characteristics of the aircraft and are also the key to building lightweight aircraft. Today's pattern airplanes have wings and stabs that are made primarily of balsa sheeting and a foam core. A wing and stab can be built quickly with these materials, and are light and very straight, all of which are major concerns for the pattern flyers. Each component for the wing and stabilizer has its specific task regarding the strength of the wing.

Wing and stabilizer cores are manufactured from expanded polyethylene foam. This foam is lightweight, approximately one to two pounds per cubic foot, and is easily cut with a hot nichrome wire. Expanded polystyrene is manufactured by feeding the granular styrene material into a steam-and-heat process. This expands the small beads. The expanding of the beads is a controlled process resulting in four different densities of bead-like material. The beads are cured in netlike hoppers to allow them to become dimensionally stable. The cured beads are injected into a vacuum-molding machine and the beads are fused with more steam, heat and pressure into large slabs. The slabs are then placed in curing rooms to ensure dimensional stability and quality control. These large slabs are cut with hot wires into smaller pieces and shipped to the airplane manufacturers for final use in foam core components in their kits.

The airplane manufacturer begins fabricating foam core components by cutting the foam into blocks the size of the wing panels. Centerlines

are drawn on the block and the inboard and outboard airfoil patterns are attached to the foam block on the centerlines. The manufacturer cuts the wing core from the foam block, using a nichrome wire attached to a power supply that heats the wire. The hot wire is pulled through the block, along the airfoil patterns, to cut the wing core from the block. This process produces the wing core, top and bottom shuck. All three components are used to create a perfectly straight wing. However, the shucks are used only during the construction of the wing and discarded after the wing is complete. The foam core is used to define the airfoil of the wing and to hold the wing sheeting in place.

The wing derives its strength from a combination of the foam core and the balsa sheeting. Balsa sheeting is lightweight, very strong and easy to work with, but weak by itself. The foam is intolerant of bending or twisting and breaks easily. However, combining the two materials in a sandwich-type construction results in a strong and light unit.

The wing and the stab use the same techniques for construction. We recommend constructing the rudder first, since a mistake here will be less costly to correct than on the wing.

Choice of adhesives for wing sheeting is very important. Virtually every adhesive except epoxy, white glue and some contact cements, will dissolve the foam. Also, avoid using any thinner near the cores. Thinner will dissolve the foam before your eyes! If you are not familiar with the technique of sheeting cores, we recommend you thoroughly read the following instructions before proceeding. It is very easy to add a lot of unnecessary weight if the sheeting process is not performed correctly.

## HONEYCOMBING FOAM CORES

One of the easiest ways to lighten your airplane, improve its roll characteristics, increase its vertical capabilities (and increase its fragility) is to honeycomb the foam core components of the airplane. Honeycombing of foam core components for a pattern airplane is not for everyone. The process does decrease weight, but it also adds to the fragility of the system. The stresses and loads of flying are not what cause problems with honeycombed components. What really causes the problems is the bouncing and banging that take place with a rough landing. Therefore, no matter what class you fly, if you still have trouble with your landing, you should not consider honeycombing your components. However, if you are proficient with your landing and are flying the advanced patterns requiring long vertical legs, quick and precise point rolling maneuvers, then honeycombing and the resulting weight savings will benefit your effort. Honeycombing of the foam core components will result in weight savings of six to eight ounces (due to reduced glue usage).

This decrease in weight has a dramatic effect on the flying characteristics of a model airplane. It has to do with the amount of mass that you're attempting to roll around the axis of the fuselage. As an example, take a piece of plywood and a piece of balsa wood of the same size and at arm's length, swing them from your leg to above your head. You will find it takes less energy to move the balsa wood than the plywood. In addition, the balsa wood stops or dampens much faster than the plywood. This is the effect honeycombing has on foam core panels. By lightening each foam core component, the control surfaces don't have to produce as much force to move the airplane. Then, and when the control surfaces are neutralized, the airplane dampens or stops very quickly without having the momentum of the extra weight to carry the airplane farther than needed.

However, with the elimination of core material, the foam core components become much more fragile. The balsa sheeting is very susceptible to punctures from fingers and sharp implements, and the components will sustain more damage from a hard landing if they're honeycombed. Although it can be accomplished, repairing damaged honeycomb cores is difficult.

Now that we have addressed both the negatives and positives of honeycombing, and you're still interested in incorporating this technique into your airplane, let's explore what is entailed in the honeycomb process. Honeycombing is the process of systematically removing portions of the foam cores and *corresponding adhesive* to reduce the weight of the component. The reduction of adhesive is the biggest contributor to the weight savings. This process is not difficult, but it will take some time (approximately two to four hours to make the templates and complete the honeycombing). Honeycombed wings are an option with some kit manufacturers and you may want to purchase this option to avoid the effort. Honeycombing incorporates the use of poster board for template material and a device called a "variac" for the power source. We've used a poster board template to cut as many as four sets of wings. The poster board templates show no sign of deterioration. There is no need to spend the time or the money to make templates out of plywood or any other material if you don't plan on going into production with your honeycombing equipment. The variac is a simple electrical device that converts AC power to DC power, and regulates the output of DC power. The variac is used to furnish power to heat the nichrome wire that cuts the foam cleanly.

**5.1.** Obtain two pieces of 6-ply poster board from your local art or paper store. It generally comes in 20"x30" pieces.

**5.2.** Lay a foam core over the poster boards and determine if you'll need to tape additional material to the end of the poster board to make two templates.



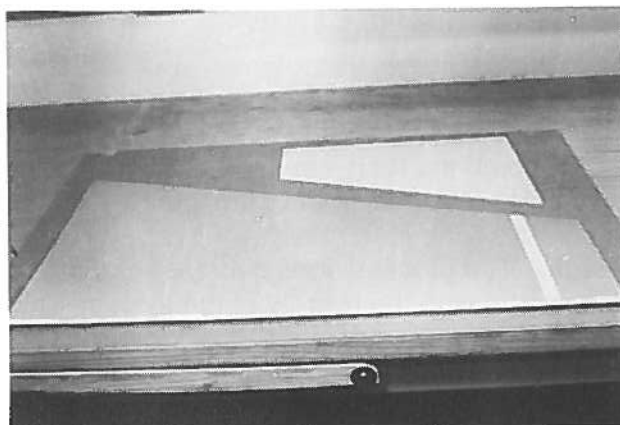
Poster Board Between Shuck And Foam Core

**5.3.** Once you have the general size required for two templates for the core, place the poster board between the foam core and the shuck. Outline the foam core on the poster board. Remove the poster board and cut the two templates.

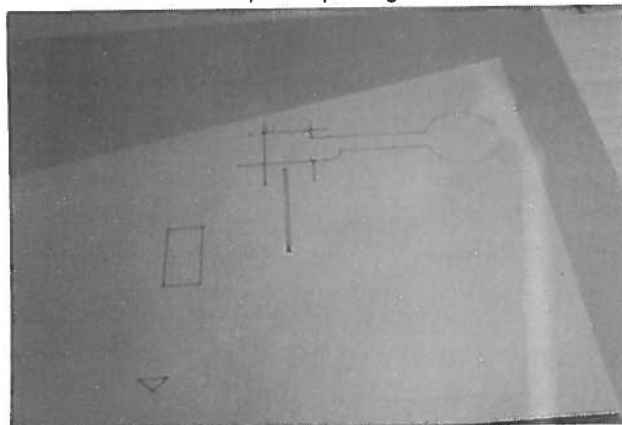


Tracing Foam Core On Poster Board

**5.4.** Tape the two templates together and then draw the locations of the landing gear plates, aileron servo, plug-in tube, aileron and facing, servo lead channel and plug-in tube false rib.

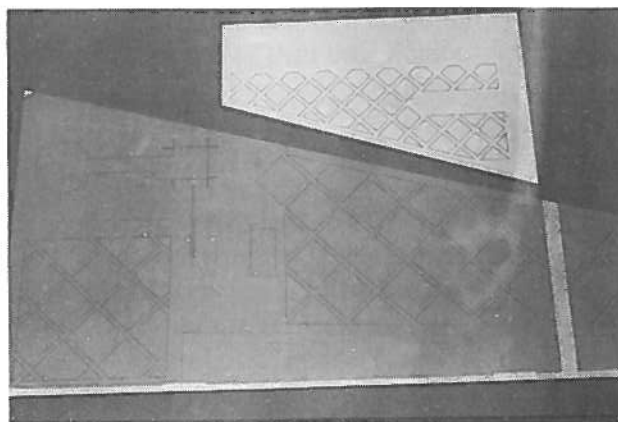


Template Taped Together



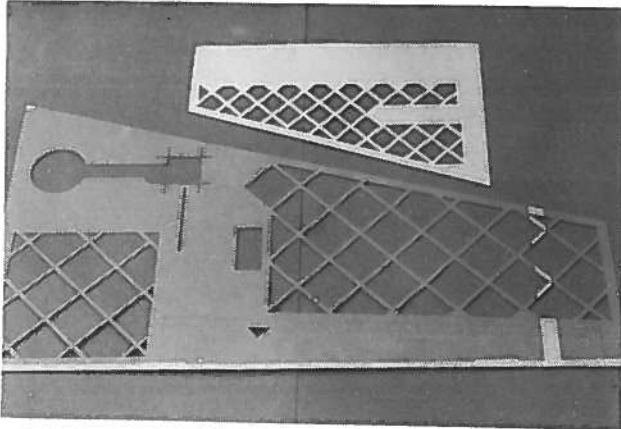
Landing Gear And Servo Boxes Located

With the critical areas drawn on the templates, lay out a honeycomb pattern that incorporates squares that are approximately 1-1/2" square and wall thickness of approximately 3/8". Lay the squares out at a 45° angle.

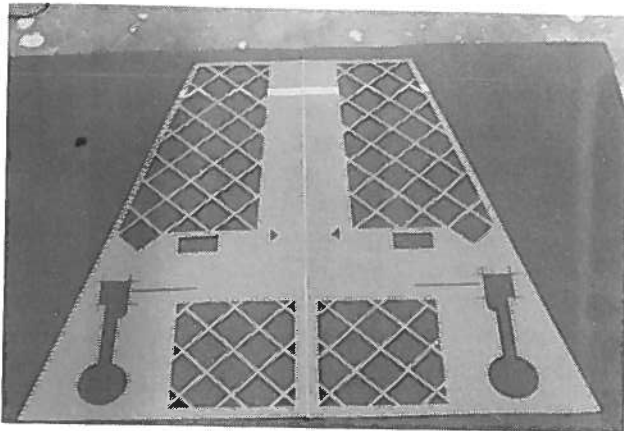


Honeycomb Pattern Drawn On Template

**5.5.** Using an X-Acto knife, cut the unwanted areas from the template, but leave the ribs between the squares. We go so far as to include the landing gear support, wheel, strut, aileron servo and reinforcements for the aileron and elevator horns in the removal of the foam core. If you cut through one of the ribs by mistake, just tape over the cut with masking tape. (NOTE: be cautious when you use the hot wire. You don't want to get it caught on the tape.)

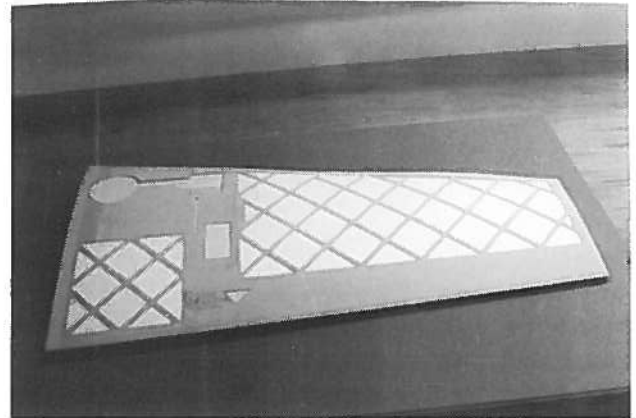


Honeycomb Voids Removed From Templates



Wing Template Opened And Ready For Core

**5.6.** Separate the templates and place one on top of the core and one on the bottom. Align them with all edges. Once aligned, tape them to the core and to each other with masking tape.

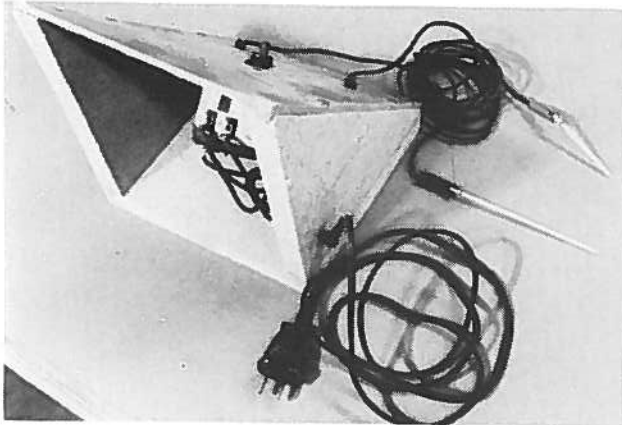


Foam Core Between Wing Templates

**5.7.** The foam is removed by using a nichrome wire and a power source to heat the nichrome wire. A power source can be obtained from your local electronics parts house. We use a device called a "variac." This is nothing more than a device that allows you to regulate the voltage or power, is very common and easily obtained. We recommend a three-amp unit, which costs approximately \$20.00. If you're going to honeycomb many airplane components, the cost is well worth it. If you should have difficulty obtaining a variac from your local electronics parts house look in the appendix and contact the electronic parts store we have listed.

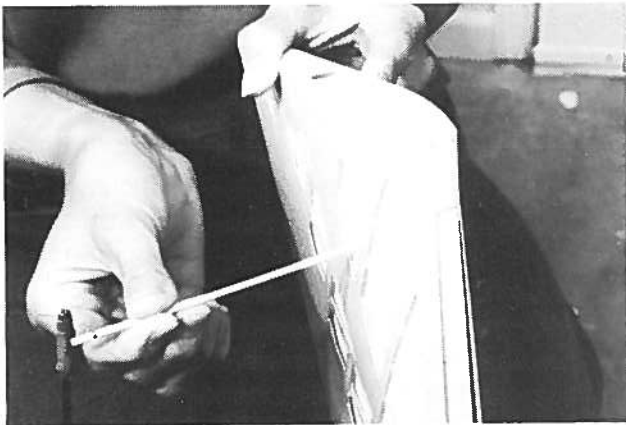
As you can see, we built a holder for our variac from scrap wood, which takes only a little time and is very easy. Just wire the variac as noted on the devices and you're ready. The nichrome wire can be obtained from your local hobby shop. Fabricate supports for the nichrome wire from 1/8" dowel skewers sharpened to a point at one end. Wrap the nichrome wire around the other end of each one.

All in all, the materials listed for honeycombing can be obtained locally at nominal cost. With a honeycombing unit of your own you can custom-cut your honeycomb patterns to your liking, once you become familiar with the process.



Variac Installed In Holder

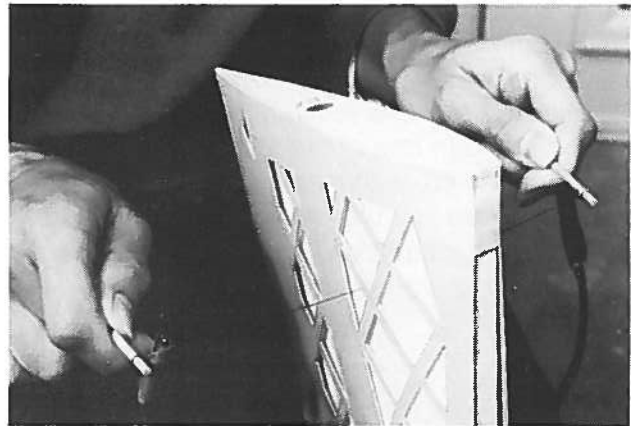
5.8. To remove the excess foam from the core, first make sure the power supply is set at its lowest setting and plugged in. Next, push the skewer through the foam block and attach the alligator clips to the nichrome wire.



Inserting Skewer Into Foam Core

Pull tension on the skewers across the nichrome wire. Next, have an assistant *slowly* turn the power up on the variac. You will notice the nichrome wire start to cut the foam. This will happen slowly at first; as the power is turned up, the movement of the nichrome wire will speed up, consequently the foam cutting will speed up. When you reach a setting that cuts the foam at a comfortable rate and does not leave big holes, then the power is set correctly. Remember, turn up the power *slowly*. If you go too fast you'll melt too much foam (and make a big mess); if you go even faster the nichrome wire will turn a bright red, light up like a light bulb and then break!

(Can you tell how fast we increased the power setting when we first started doing this?)



Cutting Voids From Foam Core

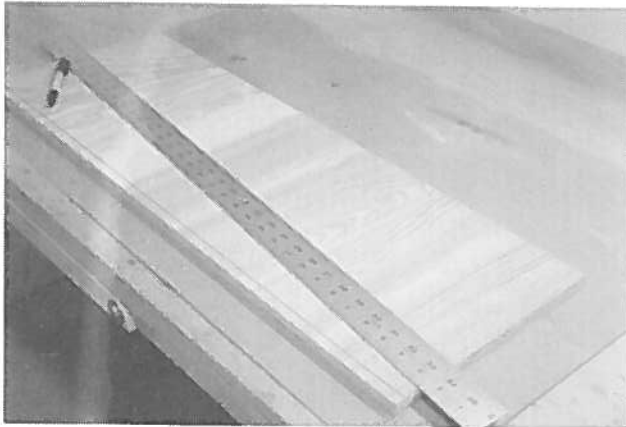
5.9. When you finish cutting out the first square, remove one of the alligator clips to interrupt the power, pull out the excess and then remove the skewers and nichrome wire. Keep repeating the process until all the excess squares are removed.

#### HORIZONTAL STAB: REMOVABLE

The advantage of this unit is the ability to remove the stab for shipping or transportation. Adjustment is seldom necessary if the stab is built and installed correctly. If you don't travel long distances to contests, or have no need to crate your airplane for shipping, you may decide the six-plus hours to add this option isn't worth it.

5.10. Cut a 1/2" hole with a sharpened brass tube in the stab cores to accommodate the phenolic tube.

5.11. Construct a jig that will guide a brass tube into the cores. Start with a piece of straight wood approximately 3'x1-1/2' wide. Draw a very straight line along one edge of the board lengthwise.



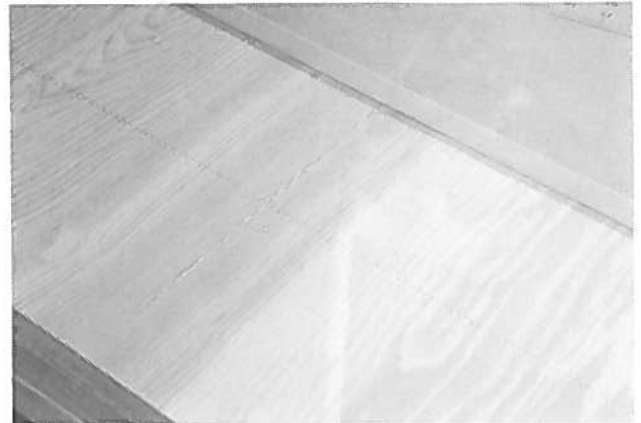
Baseline Drawn on the Baseboard

**5.12.** Glue a piece of 3/4"x3/4" triangular balsa stock to the board with the right angle edge on the baseline.



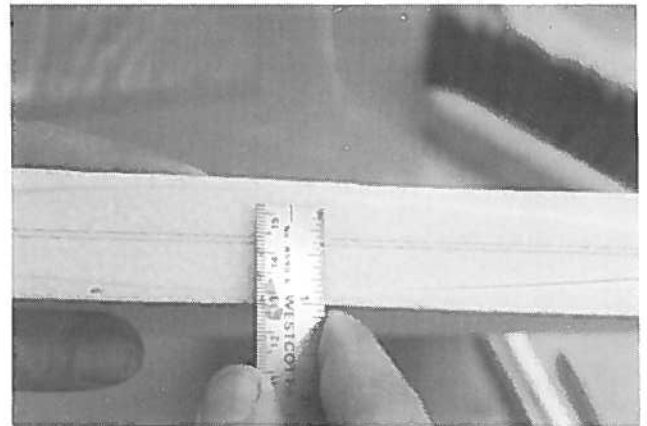
Triangular Balsa Stock Glued To Baseboard

**5.13.** From the kit plans determine where the phenolic tube is to be located from the trailing edge of the stab. Draw a line where the phenolic tube is to be located on the baseboard parallel to the triangular stock. At the center of the board draw a right angle line to the triangular stock baseboard line.



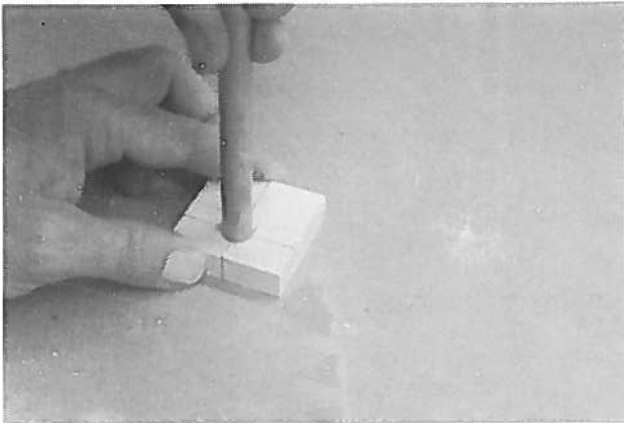
Locating the Phenolic Tube Centerline on the Baseboard

**5.14.** Measure from the bottom of the foam core stab shuck to the board with the right angle edge on the baseline.



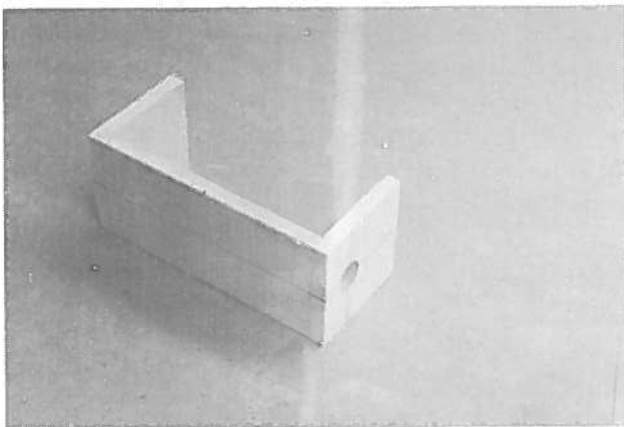
Distance From The Bottom Of The Stab Shuck To Stab Centerline

**5.15.** Construct a jig for the 1/2" brass tube. Draw two centerlines at right angles on two pieces of scrap 1/4" balsa tack glued together. "Drill" a hole through the two pieces of balsa centered on the two centerlines. Measure down from one of the centerlines the distance you measured from the bottom of the stab shuck to the centerline of the stab core. Draw a line parallel to the centerline at this distance. Insert the tube into the hole and cut through the two balsa pieces along the line you just drew. These two pieces are the sides of the jig that will be used to guide the 1/2" brass tube.



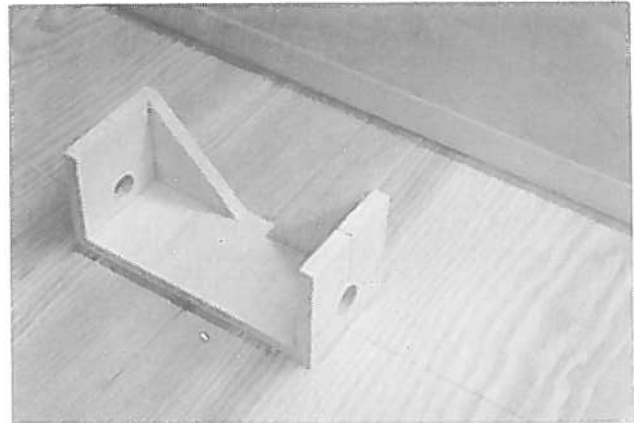
Drilling 1/2" Holes Through Two Pieces of Balsa

**5.16.** Cut a piece of 1/4" balsa the width of the two sides and approximately 4" long. Make sure the piece is square (all corners are 90°).



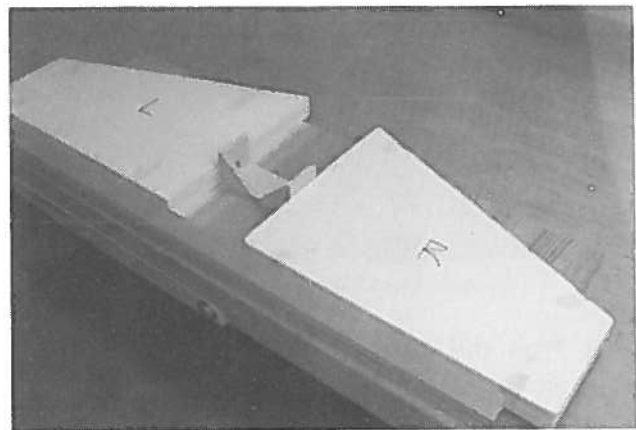
Sides and Bottom Of Jig Glued Together

**5.17.** Glue the jig over the two centerlines on the baseboard. Take your time and use an adhesive that gives you a little working time to make absolutely sure the jig is centered on the lines. Cut two braces and glue them to the sides of the jig for reinforcement and stability.



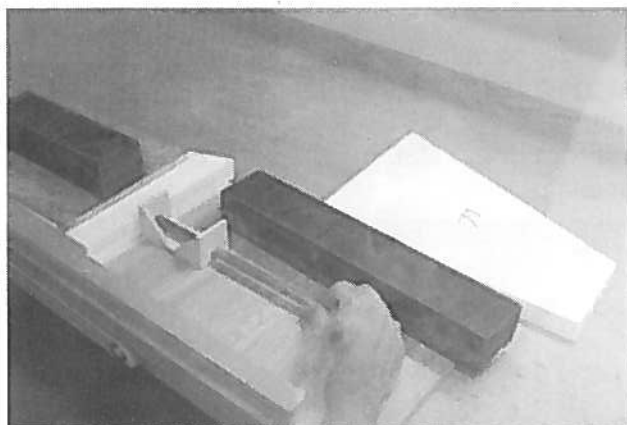
Jig Glued On the Baseboard Over the Centerlines

**5.18.** To use the jig, place the two stab halves on the jig with the trailing edges butted against the triangular balsa stock. If the stab halves are symmetrical, designate one stab half as the right and the other as the left. When you cut the hole for the phenolic tube make sure you put the left half on the left side of the jig and the right half on the right side of the jig.



Stab Halves on the Jig

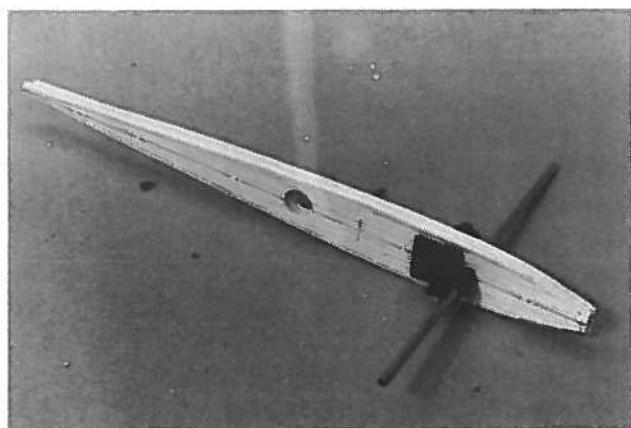
**5.19.** With the cores in the shucks and weighted, rotate the brass tube into the core, cutting the 1/2" hole. There is a left and a right side to the jig. The jig must be placed on an absolutely flat surface. With this arrangement, you are assured that the horizontal stab will be absolutely straight.



Using Jig To Drill 1/2" Hole For Removable Stab Main Support Tube

**5.20.** Following the plans, remove the excess core material from the stab root so it mates with the fuselage. This is the material that would otherwise be inside the fuselage if the stab was fixed.

**5.21.** Cut two 1/8" balsa root ribs as shown on the plans. Allow approximately 1/4" of extra material around the edge. Cut the hole for the phenolic tube in the root rib. Slide the root rib over the phenolic tube. Then slide the phenolic tube into the stab half. Trace the stab root airfoil on the root rib. Remove the root rib and remove most of the extra material.



Stab Root Ribs With Adjusters

**5.22.** If you are not using an adjustable device for stab incidence, glue a 1/8" ply plate at the anti-rotation pin locations on the back of the stab root rib and drill 1/8" holes in the ribs for the anti-rotation pins. Locate this hole as per the plans.

The picture in the previous instruction illustrates a horizontal stab incidence adjusting device installed in lieu of anti-rotation pins.

**5.23.** Prepare the fuselage for both the aluminum and phenolic tube by locating and cutting the tube holes in the fuselage to allow a *slight* amount of up, down, and side-to-side movement.



Locating Stab Support Tube In Fuselage

**5.24.** Assemble the internal phenolic tube and ply plate ring assembly for the inside of the fuselage and trial-fit it into the fuselage. Do not glue this assembly into the fuselage until the final assembly and alignment steps are performed.

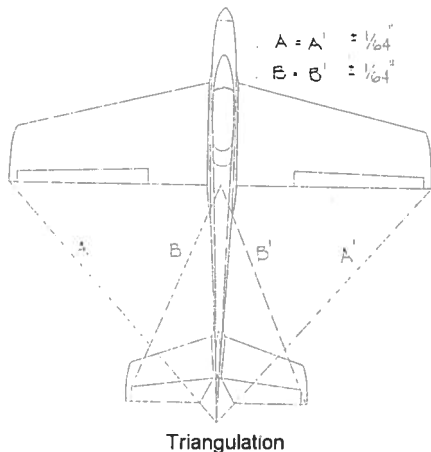
**5.25.** Once assembled, temporarily install the internal phenolic tube and ply plate assembly in the fuselage, then slide the aluminum tube through the phenolic tube, centering the aluminum tube in the fuselage.

**5.26.** Slide the stab phenolic tubes on the aluminum tube and butt them against the side of the fuselage. Slide the root ribs, with either the adjusters or anti-rotation pin retainers, over the phenolic tubes. Slide the stab cores over the phenolic tubes and against the root ribs. Remove the foam from the root of the stab core to accommodate the anti-rotation pin plates or the adjusters.

**5.27.** Nothing is more unnerving than to have a gap appear between the stab and the fuselage on the final product. The gap forms because the roots of the stabs do not match the contour of fuselages perfectly when the stab is properly aligned to the fuselage. The next two steps will eliminate the gap: with the root rib tack glued and contouring to the fuselage, and the stab aligned properly, a gap will be present between the back of the root rib and foam stab and not the front of the root rib and fuselage. This gap is eventually filled with a combination of epoxy and micro balloons. Once the sheeting is installed, the gap is no longer present.

Unless the gap is large, filling it with a small amount of epoxy will not compromise the strength of the joint between the root rib and the stab core.

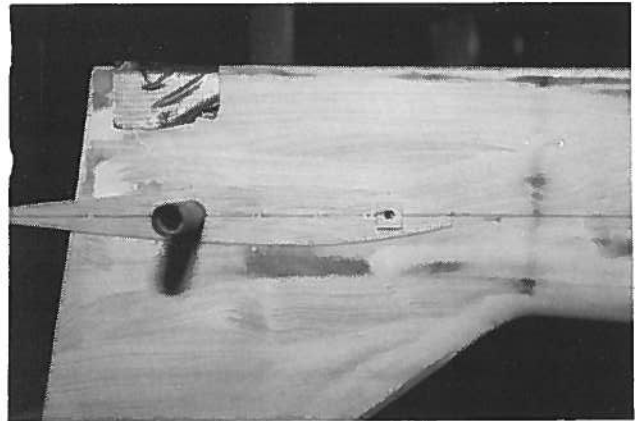
The next two steps are like rubbing your stomach and patting your head at the same time. If you manage it, you will be pleased with the final results.



Once the root ribs are flat against the stab cores and fuselage, equalize the measurements from the front center of the fuselage to the tips of each side of the stab. Align the stab so both measurements are as equal as you can get them (tolerance is  $1/32$ "). This is called "triangulation."

**5.28.** Determine the required incidence of the stab from the plans. Using the thrust line drawn

on the fuselage and an incidence meter, align the root rib with the proper incidence. Once aligned, tack glue the root rib to the fuselage with dabs of *thick* CA glue. This step will ensure the root of the stab matches the contour of the fuselage.



Root Rib And Main Support Tube In Fuselage

**5.29.** Remove the stab cores, aluminum and phenolic tubes and ply plate assembly. Drill a  $1/8$ " hole through the fuselage at the anti-rotation pin locations, or alignment pin locations, using the adjusters or anti-rotation pin blocks as guides.

**5.30.** Glue the phenolic tubes in the stab cores and attach the phenolic tube to the false ribs with slow-setting epoxy. (Note, mark the stab cores and shucks, if the manufacturer has not done it; with this marking, the stab halves can be reassembled the same way they were shipped for sheeting purposes.) Coat the stab phenolic tube with epoxy and then slide it in half way, pull it out and turn it around and push it in all the way, while twisting to distribute the epoxy. It is not necessary to slop the epoxy in the socket; use as little epoxy as possible. Remember, allow  $1/8$ " of tube to protrude from the stab core. The  $1/8$ " root rib will slide on the  $1/8$ " protruding tube.

**5.31.** Clean the aluminum tube and apply several coats of good car wax to prevent any epoxy from permanently sticking to the tube.

**5.32.** With the root rib still glued to the fuselage, carefully apply a slow-cure epoxy to the face of

the root rib to mate with the stab core. Be neat. Do not apply epoxy on the fuselage or any other component except the root rib. It is best to do this one stab at a time. If some epoxy sticks to the aluminum tube, you can twist the tube to break it loose. At this time, you will have one stab panel mated with an epoxied root rib. The other stab panel will slide on the aluminum tube but will mate with a root rib that *has no epoxy on it*.

**5.33.** While the stabs are in place and slowly curing, check the alignment of the stabs to the fuselage. To make sure the stabs are aligned horizontally, measure from the stab tips to the center of the front of the fuselage. For vertical alignment, make sure the stab is as perpendicular to the rudder post as possible. Place blocks under the stab tips if necessary. Take your time and get the alignment right; stand back and sight the setup from a distance; you have plenty of time with slow cure epoxy.

**5.34.** Once the epoxy has cured, carefully cut the root rib, which has been glued to the stab core, from the fuselage. Remove both stab panels from the fuselage, but do not remove the root rib that has not been epoxied to the stab core. Once all the components have been removed from the fuselage and nothing is glued together that shouldn't be, slide the glued stab panel on the aluminum tube and epoxy the other root rib to the other stab core as noted previously. Remember to check alignment again.

**5.35.** Once all the epoxy has cured, remove the stab panels from the fuselage and glue the anti-rotation pins to the root rib. The pins may be 1/8" brass tube.

**5.36.** Fill the gap between the root rib and the root of the stab core with a combination of epoxy and micro balloons. (Watch the weight.)

**5.37.** Harden the end of the phenolic tube at the root rib with thin CA glue. Apply a small amount of glue to the first 1/8" of tube, and lightly sand with 320 paper for a good fit with the tube. This

step will make it easier to insert the aluminum tube, and prevent fraying the phenolic tube.

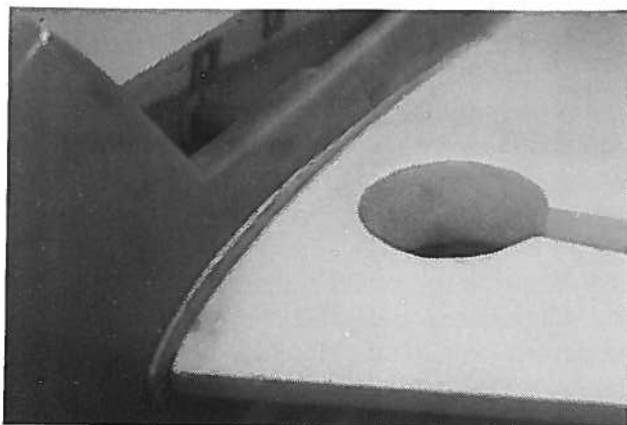
**5.38.** The stab halves may be held in place by a 4-40 machine screw or equivalent sheet metal screw, installed at the end of the tube on the bottom side of each stab half.

**5.39.** Refer to the plans supplied with the kit. You will notice a "balsa filler" at the location of the control horn. The balsa filler is used to distribute forces from the control horn into the control surface. To install this balsa filler, remove the foam core material as noted on the plans and, using Tite-bond, glue a piece of balsa (the size of the material removed) in the void. Once dry, sand the balsa filler to the shape of the foam core. Note: this is extremely important when a 4-cycle engine is used; the vibration caused by the engine will destroy the mounting area around the elevator and aileron control horns. This balsa filler, in conjunction with a hardwood dowel, will ensure that the vibration will not affect the control horn mounting area.

**5.40.** The phenolic tubes and root ribs have now been installed on/in the stab halves and the stab halves have been fitted to the fuselage. The stab halves are ready to be covered with balsa sheeting. Refer to the section titled "**WING AND STABILIZER SHEETING**" for instructions covering the next step of stab construction, the sheeting process.

## WING CONSTRUCTION

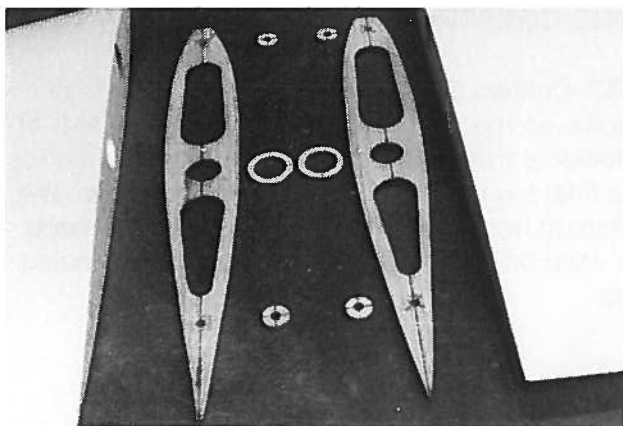
**5.41.** Cut two 1/8" balsa or lite-ply root ribs as shown on the plans. Allow approximately 1/4" of additional material around the edge of the rib for the final trimming, which will be cut off later. The lightning holes shown on the plans should only be used on the lite-ply ribs and not on the balsa ribs.



Extra Root Rib Material To Be Removed Later

**5.42.** Glue a 1/8" ply plate at the anti-rotation pin locations on the back of the wing root rib, and drill 1/4" holes in the ribs for the anti-rotation pins. Locate these holes as per the plans. In addition, if you're going to use screw hooks and springs to hold the wings to the fuselage, locate the spots for the hooks on the root rib and back these spots with small pieces of light ply. The backing will give the screw hooks additional purchase and will be less likely to pull out in the future.

**5.43.** Slide the phenolic tube into the wing and slide the root rib over the phenolic tube. Remove foam from the wing core around the anti-rotation pins and screw hooks, as needed. Once the root rib fits flat against the core, trace the core on the root rib. Remove the rib from the core, then remove the excess material from the root rib.



Root Ribs And Anti-Rotation Pin Plates

**5.44.** Fit the false ribs (the plywood plate on the outboard end of the phenolic tube) to the wing by sliding the plate into the slot, and pushing a wing tube through the hole in the wing core in the hole of the false rib. With everything in place, trace along the foam, marking the false rib. Remove the rib and cut off the excess. Refit the rib to the wing core. Sand the excess off so the false rib exactly matches the contour of the wing core.

**5.45.** Cut out a recess for the aileron servo in each wing.

**5.46.** Cut tunnels for the aileron wires and the landing gear linkage or air lines by cutting the foam with an X-Acto knife and removing the foam.

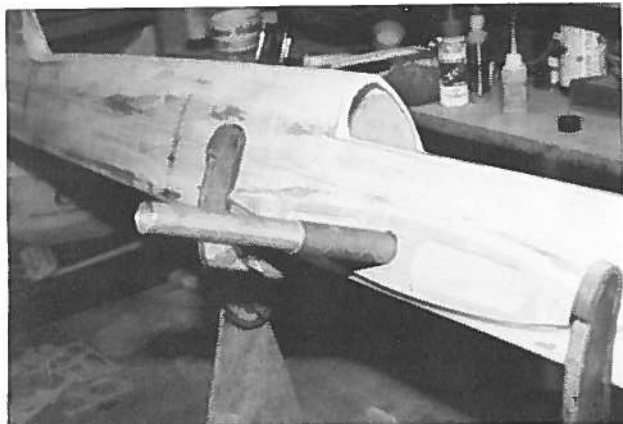
**5.47.** Prepare the fuselage for the phenolic tube by cutting holes in the fuselage approximately 1/16" diameter larger than the phenolic tube. This will allow for a *slight* amount of up, down, and side-to-side tube movement during the wing adjustment.

**5.48.** Assemble the phenolic tube and ply plate assembly for the inside of the fuselage. Trial-fit it into the fuselage. The assembly should fit tight, but not bulge the sides of the fuselage. Do not glue this assembly into the fuselage until the final assembly and alignment steps are performed.

**5.49.** Temporarily install the phenolic tube and ply plate assembly in the fuselage. Then slide the aluminum tube through the phenolic tube, centering the aluminum tube in the fuselage.

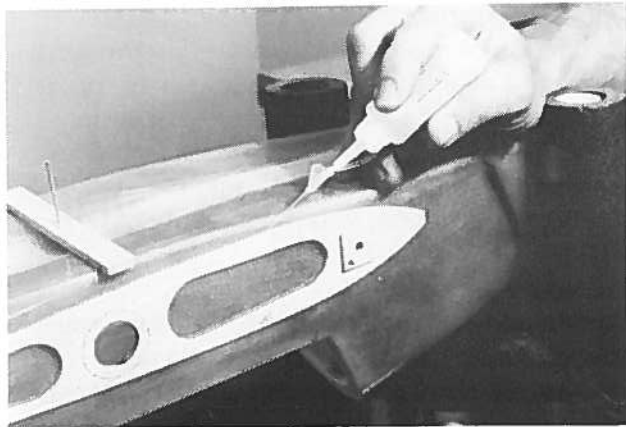
**5.50.** Slide the wing phenolic tubes on the aluminum tube and butt them against the side of the fuselage. Slide the root rib over the phenolic tube. Slide the wing cores over the phenolic tubes and against the root ribs. Triangulate measurements from the rear of the fuselage and align the wing so both measurements are *exact* (yes, tolerance is only 1/64"). Determine the required incidence of the wing from the plans.

Using the thrust line drawn on the fuselage, align the root rib with the proper incidence with an incidence meter.



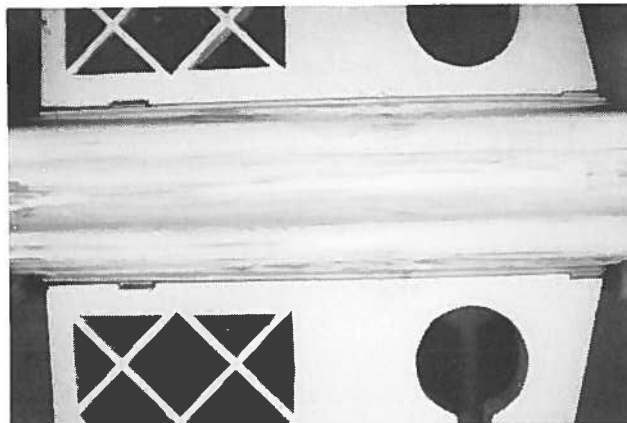
Root Ribs and Main Tube Installed In Fuselage

**5.51.** Once aligned, tack glue the root rib to the fuselage with a dab of *thick* CA glue. This step ensures the root of the wing matches the contour of the fuselage (we are following the same procedure that was outlined in the stab construction).



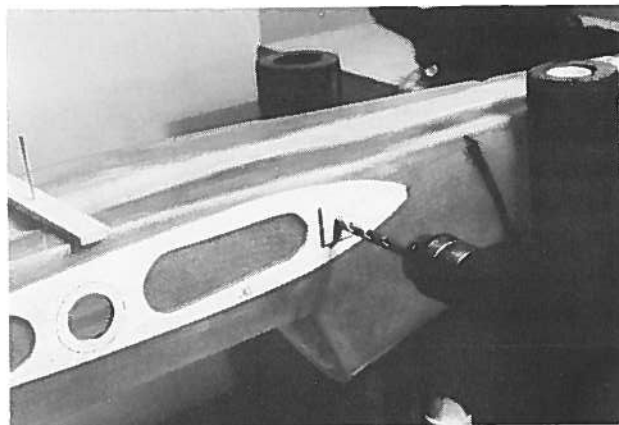
Tack Gluing Root Rib To Fuselage

**NOTE:** This is a picture taken of another airplane kit whose wings don't fit as nicely to the fuselage as the SL-1 wings. Notice the gap between the fuselage and the foam core. By tack gluing the root rib to the fuselage a gap appears between the foam core and the root rib and not between the root rib and the fuselage. This gap is then filled with a mixture of micro-balloons and epoxy.



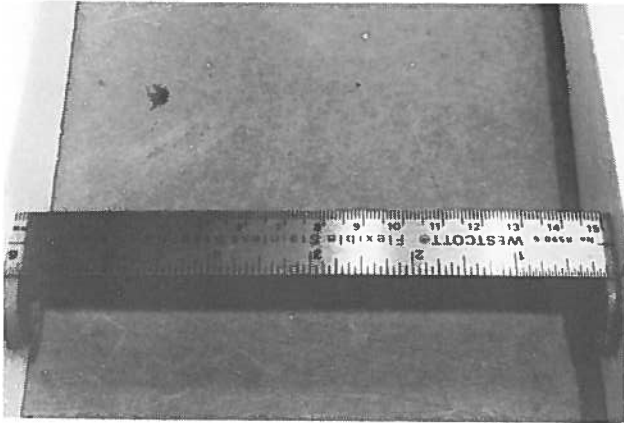
Gap Between Foam Core And Root Rib

**5.52.** Once the root rib is secured to the fuselage, remove the wing cores, phenolic and aluminum tubes, and drill a 1/4" hole in the fuselage at the anti-rotation pin locations using the root rib as a guide.



Drill Locations For Anti-Rotation Pins In Fuselage

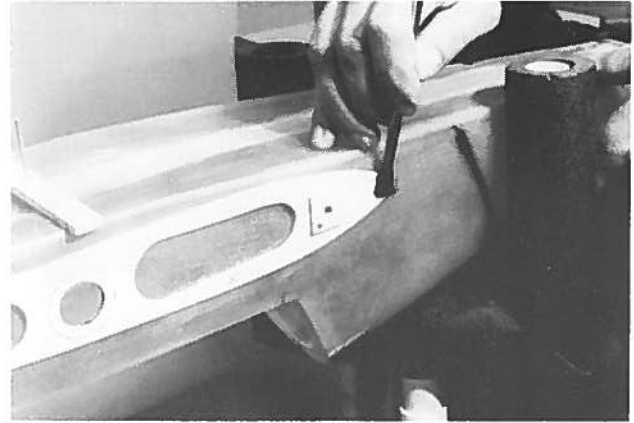
**5.53.** Glue the phenolic tubes in the wing cores and attach the phenolic tube to the false ribs with slow-setting epoxy. (NOTE: mark the end of the wing cores and shucks, if the manufacturer has not, so they can be mated the same way they were cut.) Coat the wing phenolic tube with epoxy and then slide it halfway in, pull it out and turn it around and push it all the way in while twisting to distribute the epoxy. It is not necessary to slop the epoxy in the socket; use as little epoxy as possible. Remember to allow 1/8" of tube to protrude from the wing core to slide into the root rib hole that has been cut to receive the tube.



1/8" Of Tube Extending From Core To Be Installed In Root Rib

**5.54.** Clean the aluminum tube and apply several coats of good car wax to prevent any epoxy from permanently sticking to the tube. **NOTE:** if something should happen to the aluminum wing tube, do *not* replace it with anything other than 6061 T-6 or 2024 T-3 grade aluminum. There is a vast difference in the strength of some aluminum alloys. Do *not* replace the tube with hardware store stock. This material is not suitable for our use and will buckle at very low wing loading. If this happens ... down comes da plen!

**5.55.** With the root rib still glued to the fuselage, carefully apply a slow-cure epoxy to the face of the root rib that will mate with the wing core. *Be neat; do not slop epoxy on the fuselage or any other component except the root rib.* It is best to do this procedure one wing at a time. If some epoxy sticks to the aluminum tube, you can twist the tube to break it loose. At this time you will slide one wing panel onto the aluminum tube to mate with a root rib that has the epoxy on it and slide the other wing panel on the aluminum tube to mate with the root rib that *has no epoxy on it*.



Applying Epoxy To Root Rib For Foam Core Installation

**5.56.** While the epoxy on the root rib is curing, check the alignment of the wings to the fuselage again. To make sure the wings are aligned horizontally, measure from the wing tips to the center of the rear of the fuselage. For vertical alignment, make sure the wing tips are the same distance from the work surface, and that the rudder post is perpendicular to the work surface. To ensure that the rudder post is perpendicular to your work surface, use a builder's square. Hold one leg of the builder's square on the work surface and align the rudder post with the other leg of the builder's square. Place blocks under the wing tips if necessary. Take your time and get the alignment right, stand back and sight the setup from a distance; you have plenty of time with slow cure epoxy.

**5.57.** Once the epoxy has cured, carefully cut the root rib that has been glued to the wing core from the fuselage and remove both wing panels from the fuselage, but do not remove the root rib that has not been epoxied to the wing core. Once all the components have been removed from the fuselage, and nothing remains glued together that is not supposed to be, slide the glued wing panel on the aluminum tube and epoxy the other root rib to the other wing core as noted previously. Remember to check the alignment again.

**5.58.** Once all the epoxy has cured, remove the wing panels from the fuselage and glue the anti-rotation pins to the root rib. The pins may be 1/4"

brass tube, carbon fiber rod, or aluminum rod. Avoid using wood dowels, as they wear quickly.

**5.59.** Fill the gap between the root rib and the root of the wing core with a combination of epoxy and micro balloons (and watch the weight!).

**5.60.** If you choose to install a landing gear plywood plate, refer to the instructions and plans in the kit. This is a straight forward procedure. Most manufacturers supply a cut-out for the plate in the wing core and the balsa filler pieces.

Epoxy the gear plates to the foam. Glue the balsa filler to the gear plate and sand to the contour of the wing in the immediate vicinity.

**5.61.** Harden the end of the phenolic tube at the root rib with thin CA glue. Apply a small amount of glue to the first 1/8" of tube, and lightly sand with 320 paper for a good fit with the tube. This step will make it easier to insert the aluminum tube, and prevent the phenolic tube from fraying.

**5.62.** Refer to the plans supplied with the kit. You will notice a "balsa filler" at the location of the control horn for the ailerons. The balsa filler is used to distribute forces from control horn into the control surface. To install this balsa filler, remove the foam core material as noted on the plans and, using Tite-bond, glue a piece of balsa the size of the material removed in the void. Once dry, sand the balsa filler to the shape of the foam core.

**5.63.** The wing cores are ready for balsa sheeting.

## WING AND STABILIZER SHEETING

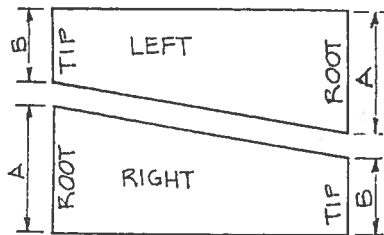
Sheeting over the wings and stabilizer serves two functions: It gives the necessary strength and support to the foam wing core to allow the panel to function as a wing and offers a substrate for the final covering of the wing. Keeping both functions in mind, it's important for the sheeting to be strong for the flying

characteristics and also very smooth for the finish. Unfortunately, balsa is not cut in widths that allow the cores to be covered with one continuous piece of balsa wood. Instead, we are burdened with the task of joining many pieces of balsa wood to create one composite piece to cover the cores; how the pieces of balsa wood are joined determines the strength and final finish of the wing.

Keep in mind that balsa wood is very soft; any wrong stroke with sandpaper or scraper will cause a dent or gouge. Treat your sheeting with extreme care! We have found that working on a piece of matt board helps alleviate gouging and scratching. *Above all, when working with your sheeting pieces, keep your work area clean. Constantly brush off the balsa dust and scraps.* Nothing is worse than sanding the face of a balsa sheet to perfection, and then turning it over to discover that there was a sliver of scrap that created a gouge.

The balsa sheets you choose for your sheeting will profoundly affect the final weight of your wing panels. Look for the lightest-weight material you can find. A rule of thumb is that if you can save a gram per sheet, you'll save an ounce of weight per wing panel. The four-six pound per cubic foot balsa is the best. You'll pay a premium price, but the weight saving is worth the cost.

**5.64.** Obtain enough sheeting to cover the wing cores, stabs and rudder. The quantity of sheeting needed can be calculated by adding the chord of the wing at the root, to the chord of the wing at the tip, and multiply by two. Then divide by the width of the balsa sheets you wish to use. To account for wing sweep, or taper, just add two more sheets of sheeting material to the total.

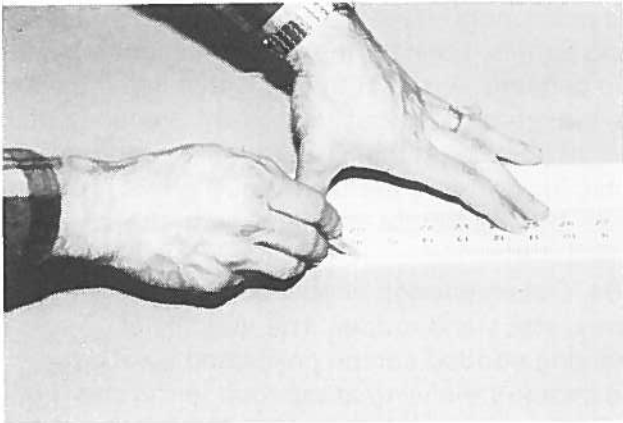


NUMBER OF SHEETING  
PIECES =  $(A+B) \times 2 \div \text{WIDTH}$   
OF SHEETING PIECE  
EXAMPLE:  $A=16"$ ,  $B=8"$   
SHT. PC. WIDTH =  $4"$   
 $(16+8) \times 2 \div 4 = 12 \text{ PIECES}$

Diagram For Determining Number Of Balsa Sheets For Sheeting

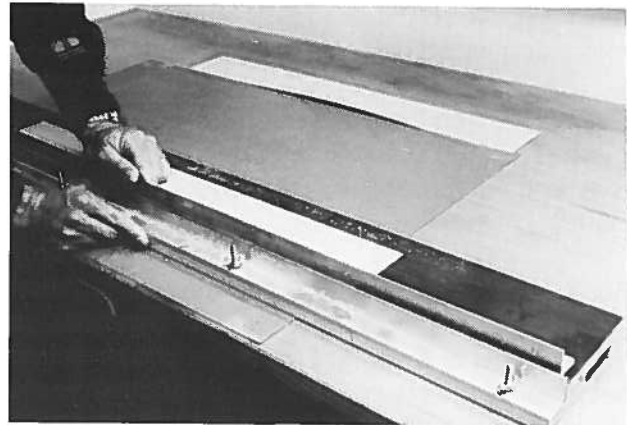
**5.65.** Sort the sheets into two stacks, according to weight, so each stack weighs approximately the same.

**5.66.** Using a 36" or 48" straight edge, cut a small sliver of balsa from the edge of each sheet of material. This will remove bends and warps from the edge and ensure the sheets will mate together without gaps.



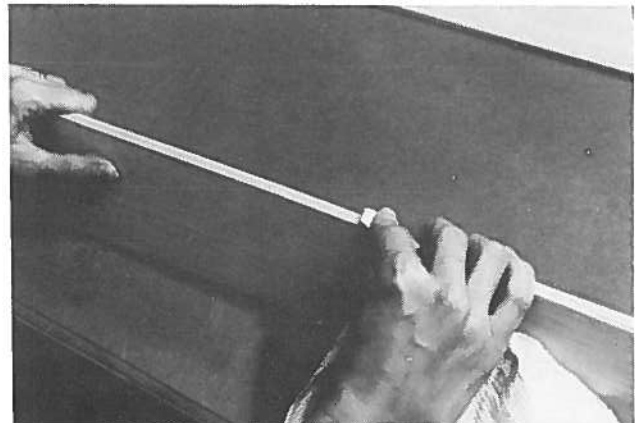
Removing Bends And Warps From Sheeting

Another handy device, which we've built to square the edges of balsa wood, is an edge sander. It consists of a wood base and a very straight piece of material that is covered with sand paper. Our edge sander uses an aluminum angle that is bolted to the wood base. The edge of the sheeting pieces slide along the sand paper to sand the edge straight.



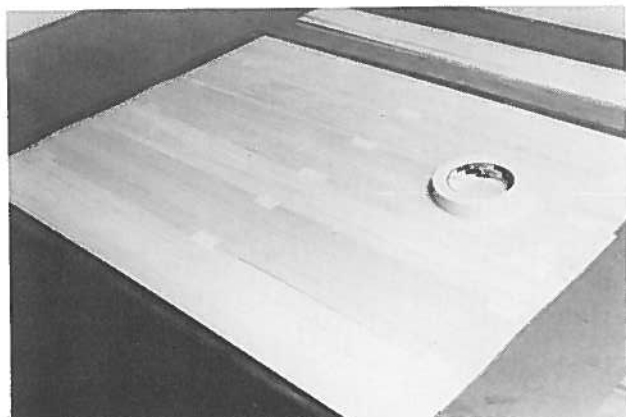
Using An Edge Sander To Straighten Edges Of Sheeting

**5.67.** Prior to taping all the pieces together, gather all the sheets and rub some Duco cement on the edges. You do this to allow a coating of glue to penetrate the edges of the balsa, which allows the second coat of glue to bond the edges together. If you don't do this, the only coat of glue you apply will be wicked into the wood so quickly that there will be no bond between the sheets, and the assembly may fall apart.



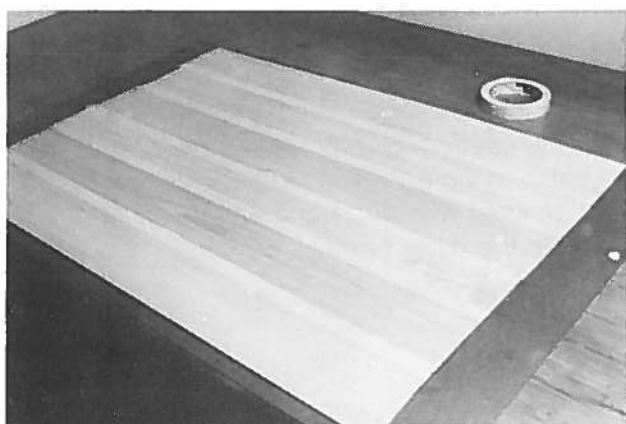
Spreading Duco Cement To Edges Of Sheeting

**5.68.** Pick one stack of material and lay it out on your work surface, butting the edges closely together. Using pieces of masking tape, join the edges at three spots along the joint.



Spot Taping Sheeting Together

**5.69.** Once all the pieces are temporarily taped together, place a continuous piece of masking tape over each of the joints.



Taping Edges Of Sheeting

**5.70.** Repeat the above process with the other stack of sheeting.

**5.71.** You now have two large sheets of taped sheeting. Each sheet will cover one wing panel. Measure and mark the wing panels on the large balsa sheet. Once satisfied that the large sheet will cover the wing panel, cut it into two pieces diagonally to match the shape of the wing.

**5.72.** The sheeting edges are now ready to be glued together. Using the following technique, you can assemble sheeting that won't show seams through the covering and is quick to assemble. But before you start gluing the sheeting together, be aware that the process

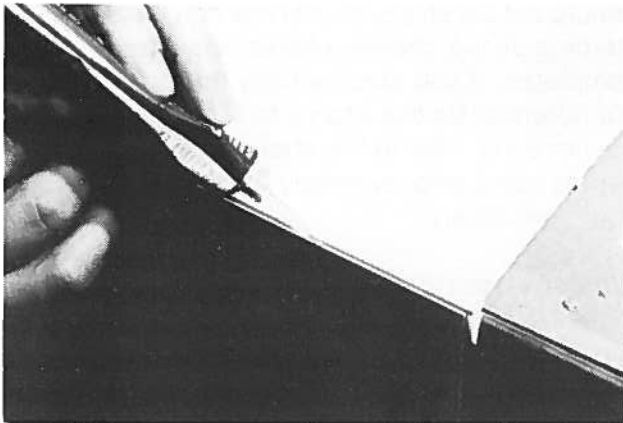
should not be stopped until the first pass at sanding all the sheeting faces has been completed. If you stop halfway through, there is the potential for the seams to show through on the covering. Gluing the sheeting for two wing panels takes approximately one hour, so gauge your time wisely.

We don't use CA adhesive to stick the edges together. CA is harder than balsa. When the joint is sanded, the seam will remain as a ridge and is difficult to sand down. In addition, it has been our experience that if plastic covering is used over the sheeting with CA seams, the heat from the sealing iron seems to react with the CA and the seam becomes even more obvious under the covering. The adhesive we prefer to use is Duco cement. It is clear and easy to sand, very much like balsa wood itself.

Prepare the Duco cement tube by inserting a Testors glue tip on the end. You can buy this glue tip from any hobby shop that carries plastic models. The tip allows you to extrude a very small glue line on the joints of the sheeting.

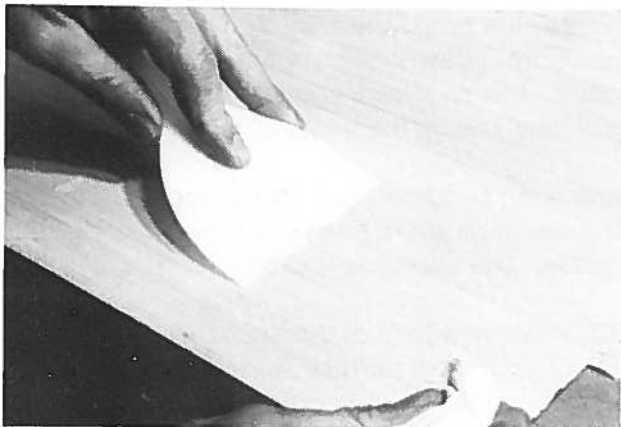
Many good builders have had success using CA adhesive to glue the edges of their sheeting together. The choice is yours.

**5.73.** Position a joint of the sheeting over the edge of your work surface with the taped side down. If everything is taped together properly the joint should open up just enough to apply the glue. Lay the glue tip in the crack of the joint and apply a small bead of Duco cement along the entire length of the joint.



Edge Gluing With Cement And Testor Tip

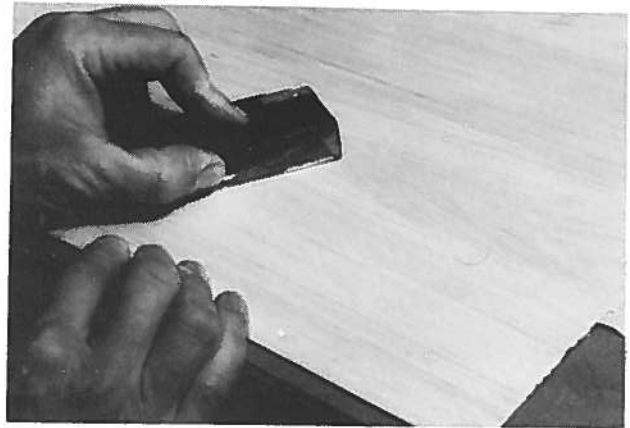
**5.74.** Once you cement all the joints of one panel, lay the panel on your work surface using a plastic scraper at a very low angle to remove the excess cement. Keep the scraper clean by removing the excess glue from the scraper with a paper towel.



Removing Excess Cement From Edge

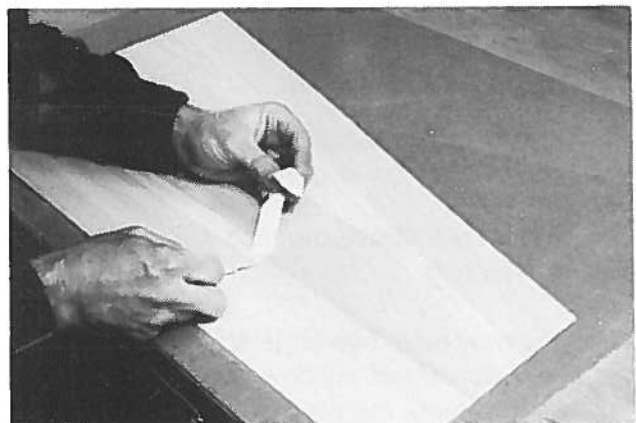
**5.75.** While the cement is still wet, sand the joints lightly with 200 grit sandpaper. What you're doing is creating balsa dust that works into the joint and fills the small cracks to a smooth finish. *Do not sand much because the tape on the back causes a ridge to form on the front side.* If you sand too much on the front, you'll lower this ridge down to the surrounding wood. When the tape is removed from the backside, the balsa will be thinner at the joint and the joint will show as a seam on the final product. Sand lightly, just enough to create dust

and fill the cracks but not enough to form a depression.



Lightly Sanding Front Face Of Sheeting

**5.76.** Once all the panels are glued and sanded on the front side it is time to remove the tape from the backside. When you remove the tape, the joint will be fragile because the cement is still damp under the tape! Proceed with extreme care and caution. Gently pry up the tape from the balsa using an X-Acto knife. Pull the tape back on itself with one hand and press on the joint with the other hand.



Carefully Removing Tape From Face Of Sheeting

**5.77.** With all the tape removed from one of the panels, you'll notice that the adhesive is damp. Sand the joints as you did on the front with 200 grit sandpaper. Create balsa dust and fill in the joint. Continue removing the tape and sanding each panel until you're done.

**5.78.** Let the panel joint dry thoroughly overnight. Once the panels are dry, sand them vigorously to remove the appearance of joints. Start with 200 grit and work up to your choice of sandpaper.

## SHEETING AND FACING THE WING AND HORIZONTAL STAB

Prior to sheeting the wing, you should have installed:

- The outboard false rib
- Wing tube
- Root rib
- Balsa box for the aileron servo
- Triangular balsa block for the aileron control horn
- Landing gear box or plate
- A tunnel for the aileron servo control wire

Prior to sheeting the stab, you should have installed:

- Stab tube
- Root rib
- Triangular balsa block for the
- Elevator control horn

We have explained how to install each of these items.

**5.79.** Locate a flat surface on which to sheet the cores. The bench must be capable of remaining flat with 80 pounds of weight on it. Don't assume your bench is flat. Check it with a straight edge.

**5.80.** Keep the cores in the blocks from which they were cut.

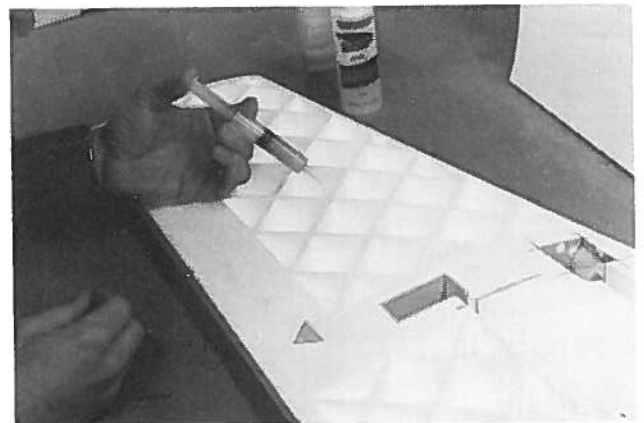
**5.81.** Lightly block sand the cores to remove the surface fuzz and vacuum the cores thoroughly.

**5.82.** Apply epoxy resin to the foam cores. This can be done by mixing a small batch of slow cure epoxy resin and then filling a Monojet syringe with epoxy. Sig packages and sells the Monojet syringe in hobby shops.



Filling Monojet To Apply Epoxy to Sheeting

**5.83.** Using the syringe, eject thin ribbons of epoxy resin, approximately  $1/32''$  to  $1/16''$  wide, onto the foam. In the large foam areas you can cross hatch the resin by spacing the ribbons about 1" apart. In the honeycomb areas, apply a single ribbon to the foam ribs. Make two passes on the edges of the wing, approximately  $1/4''$  apart. *Remember, the less glue, the less weight, the better the airplane will fly.* It does not take much epoxy resin; we use a little over two ounces of epoxy resin on the wing (which covers both sides).



Spreading Epoxy On Foam Core

**5.84.** Position the sheeting on the epoxy resin cores. Place the cores and sheeting in their original shucks. Align all the corners and then tape the entire block together with masking tape. The tape secures the block together and makes it easy to check alignment. If, after taping the

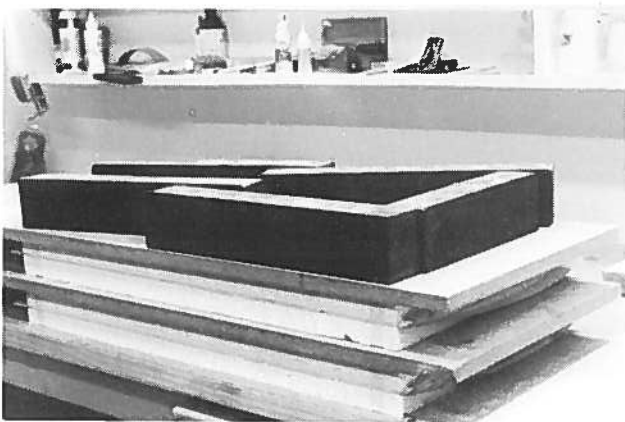
assembly together, you find that it's out of alignment, release the tape, realign and re-tape.

**5.85.** Place the foam block, with the core and sheeting inside, on the table with the bottom of the wing down.

**5.86.** Check to make sure everything is aligned in its final position and place a piece of 3/4" plywood or particle board (slightly larger than the block) on top of the stack.

**5.87.** Add weights to the board. Books, fuel or milk jugs filled with water work well. Distribute the weight evenly. Approximately 30 pounds will do for the stab and 80-90 pounds for the wing.

The cores have been cut from a foam block on a ground metal plate and weighted during the cutting operation. Because of the nature of the foam, some bowing may occur when the weight from the cutting process is removed. This bowing will disappear when the core is weighted down on a flat surface. By using slow cure epoxy and the weight, the wing will settle into the original cut position and produce a straight and true wing (if the working surface is not warped or twisted).



Sheeted Cores With Weights

**5.88.** Inspect for bowing or twisting of the wing panels while the block is weighted and on the flat working surface. To check this, use a good metal straight edge on each side and at the ends of the work surface. Double-check your work. Take your time to ensure everything is

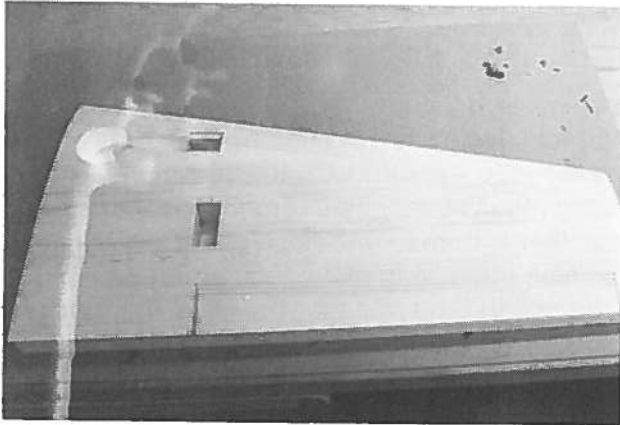
straight before you let the epoxy resin cure. If the sheeting is not pressed down tight or a slight bow is evident, and shimming of a surface is necessary to obtain a flat surface use playing cards or poster board shims. Sometimes redistributing the weight is necessary. Do one wing/stab block at a time until you get the hang of it.

**5.89.** Allow the assembly to cure for at least 24 hours, and then remove the weight from the core. Trim the excess sheeting to the foam core. Compare the left and right halves. Shape the panels so they match *exactly*.

**5.90.** Using an X-Acto knife or a razor blade, slice 1/4" off the wing/stab core trailing edge. Glue a piece of 1/4" square balsa on the trailing edge using Tite-bond or epoxy. When dry, shape the trailing edge using a razor plane and sanding block. *Do not* try to get a sharp trailing edge. A blunt trailing edge, 3/32" to 1/8" thick, makes the airplane hold a line (whether vertical or horizontal) better.

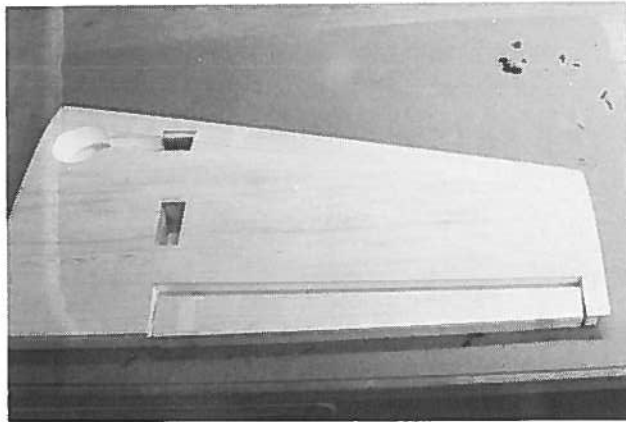
**5.91.** Glue on and shape the leading edges and the tip blocks. First, shape the leading edge to the adjacent sheeted surface, then gently pinch the panel between your knees. Take a piece of 200 grit sand paper in both hands and sand the leading edge as if you were buffing a pair of shoes. This will produce a uniform round leading edge the entire length of the panel. While sanding, stop often and check by sighting down the leading edge. Take care to not remove too much material from either the ends or the middle. NOTE: This technique may produce too blunt of a leading edge for the higher class flyers (the leading edges on the wings of the higher class airplanes *should* have a sharper leading edge to enable them to perform "snap" maneuvers more easily).

**5.92.** Lay out the ailerons on the wing panels and the elevators on the horizontal stab panels with a fine-line marker. Include an allowance for the balsa facing on both the wing and aileron or the stab and the elevator.



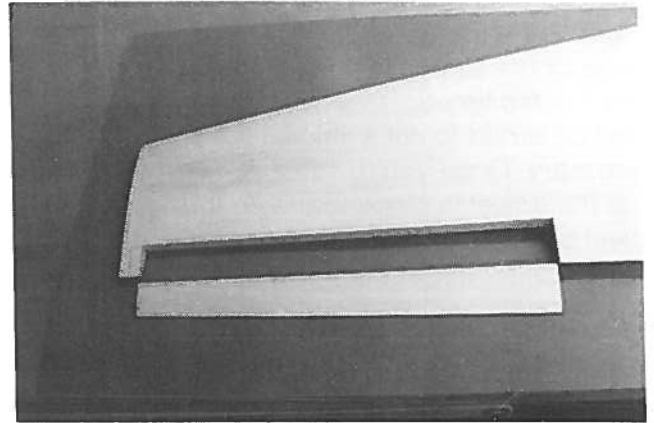
Layout Of Ailerons On Wing Panels

**5.93.** Cut out the ailerons and/or elevator using a bandsaw or jigsaw.



Ailerons Cut From Wing Panels

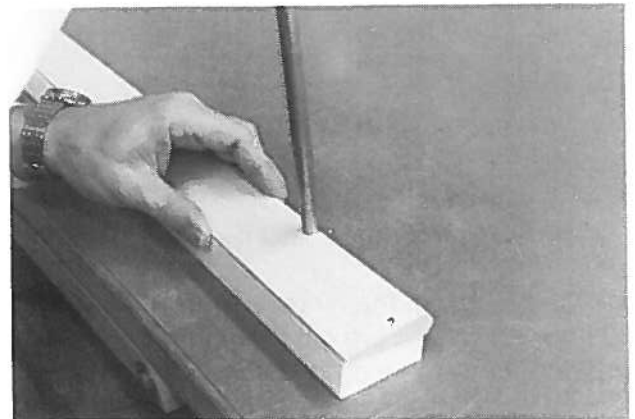
**5.94.** Glue the 1/4" facing, and the 1/16" end caps with Tite-bond or an equivalent glue to the ailerons and/or elevators. Take your time and do not induce a warp into the aileron when gluing on the facing.



Aileron And Wing Panel With Balsa Facing Applied

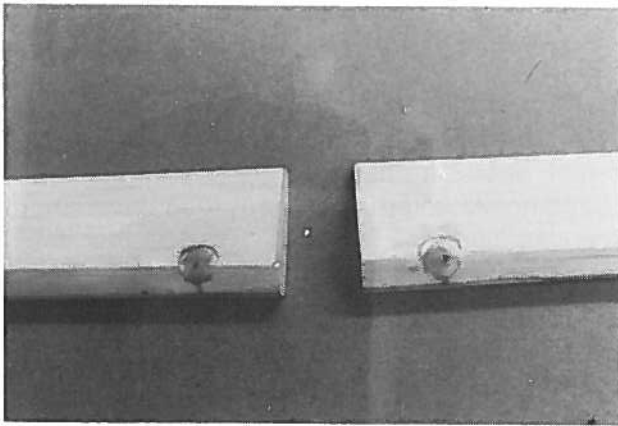
**5.95.** Trim and sand the facings. Bevel the aileron leading edge to allow at least 15°-20° of travel on each side of center. Use a long block for sanding. An alternative method to bevel the aileron leading edge is to attach sandpaper to a large board. Make it longer than the aileron. Grasp the aileron in both hands and establish the appropriate angle for the aileron face against the sandpaper. Then slide the aileron back and forth until the appropriate angle is sanded into the aileron leading edge.

**5.96.** If you're going to use a hardwood dowel aileron horn, remove a plug of sheeting and balsa filler using a brass tube the diameter of the hardwood dowel (do it straighter than shown in the picture). This area should already be backed with a balsa filler as noted on the plans. Refer to step 5.31 for the stab, and step 5.54 for the wing.



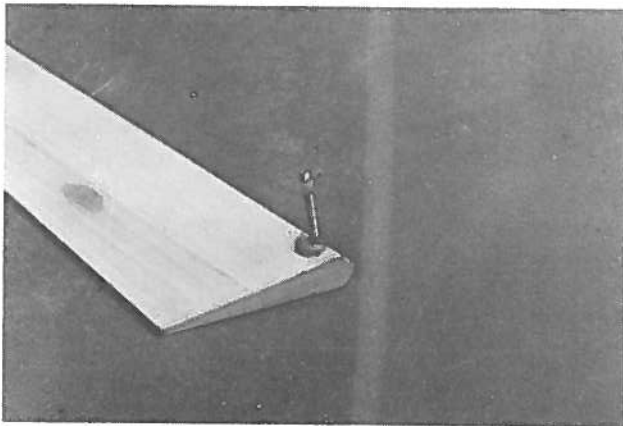
Cutting Hole In Aileron For Hardwood Dowel Reinforcer

**5.97.** Cut the hardwood dowel to the proper length. Slide the dowel into the hole. Trace the shape of the aileron around the dowel using a pencil or felt tip pen. Cut the dowel to the lines. Don't be afraid to cut a little bit more than necessary. Once you're satisfied with the fit, glue the dowel in place. Sanding the hardwood dowel adjacent to the soft balsa wood is tricky. Therefore, try to get the dowel cut and sanded as accurately as possible before gluing into place. Then apply balsa filler and sand to the contour of the surrounding area.



Hardwood Dowel Reinforcer Installed And Shaped

**5.98.** Drill the dowel for a control horn bolt-size of your choice.

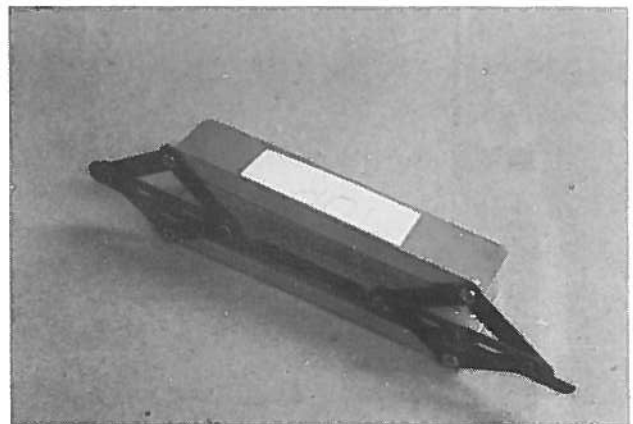


Control Horn Installed In Hardwood Dowel Reinforcer

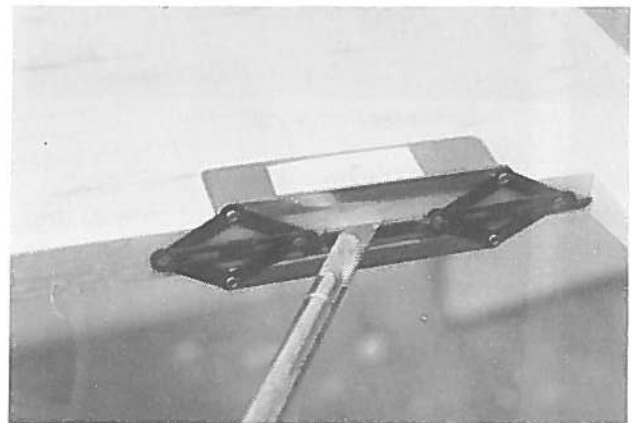
**5.99.** Mark and slot the hinge locations, making sure that the hinges are centered. Make absolutely certain the control surface is in perfect alignment with the wing. The top control surface must be exactly aligned with the top

surface of the wing. The same applies with the bottom of the wing and control surface.

An absolute must for this operation is a Tetra hinge tool. It can be obtained from Steve's Hobbies (see Appendix C). It gives you perfect hinging results every time. The important point to remember is to mark the "top" of the tool. Then, each time you use it, make sure you're working on the top surface of either the wing/stab panel or the aileron/elevator surface. This will ensure that the distance down to the hinge line is always the same. We swear by this tool!



Tetra Hinging Tool

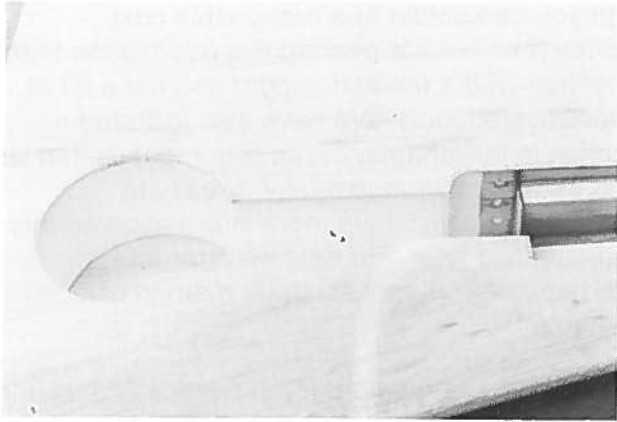


Hinge Slot Cut In Wing Panel And Aileron Using Tetra Hinge Tool

**5.100.** Remove the sheeting for the aileron servo cut-out in each wing. Glue in the mounting rails so that the control wheel protrudes just above the surface.

Remove the sheeting covering the landing gear plates and wheel wells, as required, to allow

installation of the retract mechanism. The wheel wells may be lined with 1/32" balsa.



Wheel Well With Balsa Sheeting Removed

## Chapter 6 ASSEMBLY

### IMPORTANCE OF ALIGNMENT

The importance of the final assembly and alignment of a pattern airplane cannot be over-emphasized. You can spend hours sanding and finishing and assembling the final components and ruin the entire effort if you don't use care and accuracy during the assembly and alignment process. It is here you will determine if the airplane you've built will fly straight and true or corkscrew through the air like some uncontrollable beast. All of your building efforts lead up to this critical step. From here on, take your time. If something is not quite *perfect* then take the time to disassemble it and repeat the step. It pays dividends when you watch your completed airplane rise off the runway and track through its first few flights like it was on a string. A great deal has been written about trimming an airplane (which we will cover later), but we have seen very little written about alignment during construction. This step is critical. If you can build your airplane straight and true, there should be very few trim problems. Therefore, final assembly and alignment is actually the first and most critical step of trimming your airplane. There is now a video on the market that addresses alignment. It is very good. We recommend you obtain a copy of it from the supplier. Further information see the Appendix.

### WING INSTALLATION AND ALIGNMENT

The alignment process we recommend is based on making measurements relative to only the airplane, not on measuring it to a fixed point away from the airplane. Some builders will position their models on a table and then take measurements from this table to the airplane. We used to align our airplanes this way, but we found that the table had to be absolutely flat and the airplane could never be bumped during the process or we'd have to start all over. We recommend our process because it eliminates the need for a perfectly flat table for measurements and relies on very simple tools

that you can obtain at a reasonable cost.

*Remember, we are gearing this information to the beginner with a modest budget and not a lot of sophisticated tools.* We have also included a section in this chapter on an alignment jig that we find very effective and relatively easy to construct. We will have more information on this alignment jig later. For now we offer an inexpensive and very accurate method of alignment.

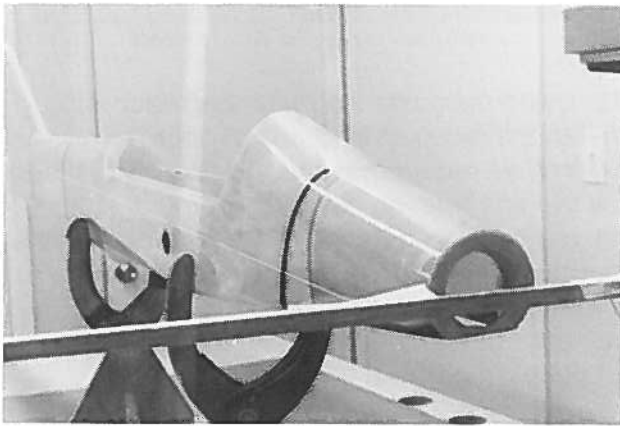
Three tools are required for this process: a plumb bob, an incidence meter and a carpenter's level. The incidence meter we use is a homemade version. We saw this version in a modeling magazine and decided it was going to be an absolute necessity in our shops. It's easy to build the supporting structure, and then attach it to an existing marketed incidence meter (refer to the drawing on the construction of this meter in the Additional Topics chapter). After you've constructed this incidence meter you're ready to assemble and align your airplane.

At this point, both wing panels are complete, but the interior phenolic tube has not been secured to the fuselage. In addition, the anti-rotation pin plywood reinforcements to be mounted inside the fuselage are not yet installed.

Mark a centerline on the fuselage rudder post, and temporarily install it into the fuselage using masking tape.

Draw a reference line along each side of the fuselage. First, locate the centerline of the engine on the front of the fuselage. Next, identify where the reference line should be located on the back of the fuselage using the plans furnished with the kit. Install a piece of balsa with one face across the centerline of the nose ring of the fuselage. Using a string, tape one end to the mark on the rear of the fuselage. Stretch the string to the front and tie it to the balsa piece on the centerline of the nose ring. Move the string close to the fuselage. As the string makes contact with the

fuselage mark its location. Work from the rear of the fuselage to the front. Using a straight edge, draw a line from the front of the fuselage to the rear through all of the little marks. Repeat the process on the other side of the fuselage. It's important that the lines on both sides of the fuselage start at the same point at the front of the fuselage and end at the same point at the back. Take your time and be accurate because these reference lines are used for the final alignment of the airplane. If they're off, the alignment will be off and the airplane will not fly straight.



Establish Centerlines On Fuselage

**6.1** Place the fuselage in a cradle upside down.

**6.2.** Enlarge the hole on one side of the fuselage for the main wing tube. Enlarge the four holes in the fuselage sides for the anti-rotation pins vertically, both up and down from the center.

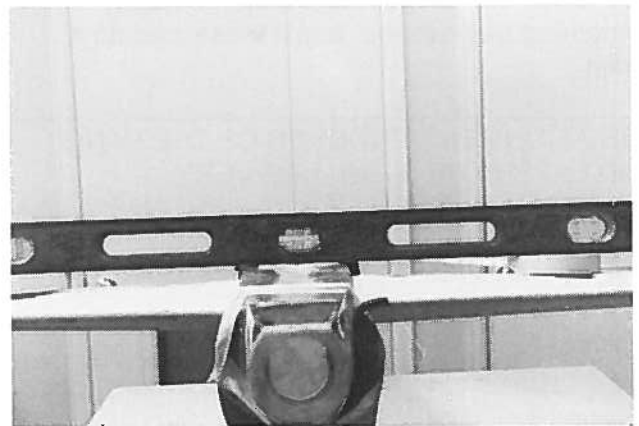
**6.3.** Slide the interior fuselage phenolic tube into place. Slide the aluminum tube through one side of the fuselage through the phenolic tube, and out through the other side of the fuselage.

**6.4.** Install the wings on the tube.

**6.5.** The fuselage is in the cradle upside down and the wings have been temporarily installed on the aluminum tube. Using a plumb bob or a carpenter's level, line up the rudder post so it's perfectly vertical and then secure it into the cradle with masking tape.

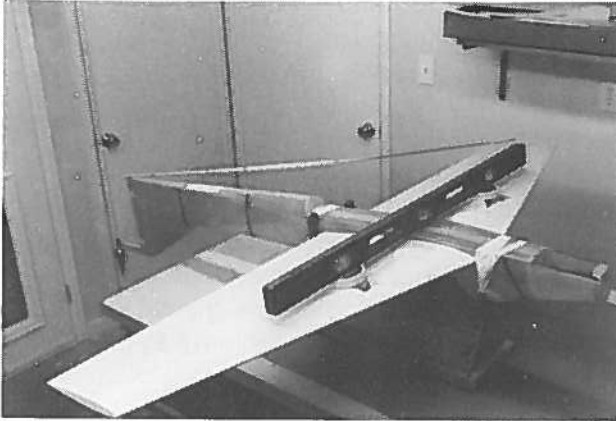
**6.6.** Place a carpenter's level on the wing perpendicular and horizontal to and over the fuselage. Support each end of the level on blocks placed on the wing panels. Use the blocks to raise the carpenter's level above the fuselage so the level is measuring only the pitch of the wing without touching the fuselage. Place the blocks over the wing tube at the same exact locations on each wing panel. If the level is placed over the wing tube then adjusting the wing incidence later on will not affect the wing alignment to the fuselage.

**6.7.** With the rudder post perfectly vertical, raise or lower the appropriate wing tip until the wing is level. Once level, secure the wing temporarily in this position. Do not glue anything yet! **NOTE:** We have now ensured that the wing is perfectly perpendicular to the rudder post. Look closely at the picture and you can see the plumb bob line rising vertically from the bubble of the level.

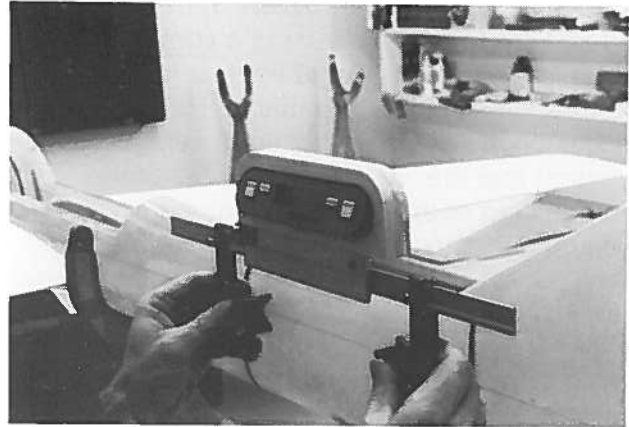


Leveling And Squaring The Wing To Fuselage

**6.8.** With the wing level and perpendicular to the rudder post, align the wing perpendicular to the axis of the fuselage. Use the triangulation method shown above. For triangulation, we use a ruler and two pieces of piano wire. (An old carpenter's tape cut to a workable length that has a hole drilled in one end also works well.) Drill a small hole the size of the piano wire at the rear of the fuselage and in front of the wing on the centerline of the fuselage. Glue the wire in the holes. Measure from the back of the fuselage to the wing tips. Adjust the wing back and forth until the lengths are within 1/64" of each other.



Leveling, Squaring And Triangulating



Leveling The Fuselage For Wing Incidence

**6.9.** Once again, check that the wing is perpendicular to the rudder post vertically and perpendicular horizontally to the axis of the fuselage. When you are satisfied all is perfectly aligned, use thick-set CA glue and tack-glue the phenolic wing tube to the fuselage. Check all your dimensions again to ensure accuracy. If something has slipped, pop it loose and do it again.

THE ALIGNMENT PROCESS OF THE WING, AND LATER THE STAB, ARE VERY IMPORTANT TO HOW YOUR AIRPLANE WILL FLY. THE IMPORTANCE OF PROPER ALIGNMENT CANNOT BE OVER-EMPHASIZED!

**6.10.** When everything has been tack glued in place, reposition the airplane in the cradle right side up.

**6.11.** Now the wing has been secured vertically and horizontally. What remains is to establish the incidence of the wings. Adjust the centerline of the fuselage so it has zero incidence.

**6.12.** Using an incidence meter, set each wing panel to the required fractions of degrees of incidence as required by the building instructions. Slide the anti-rotation pin reinforcement plates (that you fabricated out of 1/8" plywood) over the anti-rotation pins and press them firmly against the fuselage. Using thick-set CA glue, tack-glue either the fronts or backs in place (do not glue both plates in place at this time).

**6.13.** Check the incidence alignment again. Once satisfied everything is correct, tack-glue the remaining anti-rotation pin reinforcement plates into position.

**6.14.** Check all the alignment dimensions again: wing to rudder post vertically, wing to fuselage horizontally, and wing incidence. When all is correct, glue the components permanently in place using thin CA.

### HORIZONTAL STAB INSTALLATION

**6.15.** Slightly enlarge one hole on one side of the fuselage for the stab tube. Enlarge the two holes in the fuselage sides for the anti-rotation pins.

**6.16.** Slide the interior fuselage phenolic tube into place inside the fuselage, through the back of the fuselage or rudder post area. Slide the aluminum tube through one side of the fuselage through the phenolic tube and through the other side of the fuselage.

**6.17.** Install the stab halves on the tube.

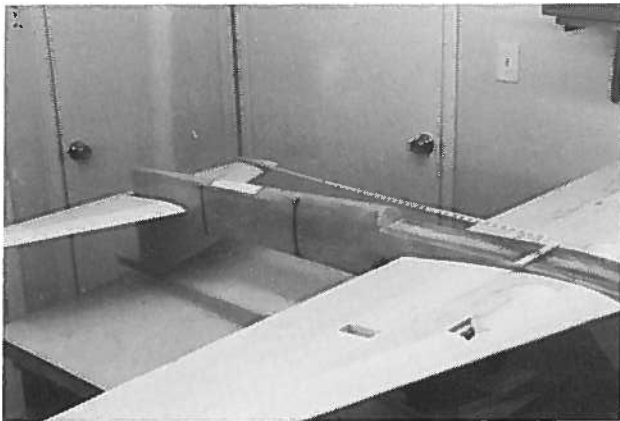
**6.18.** Install the wing.

**6.19.** With the fuselage in the cradle upside down, and when the wings are in place, temporarily install the stab on their aluminum tube.

**6.20.** Raise or lower the appropriate stab tip until the stab is level (as noted before in the wing alignment section). Once level, temporarily secure the fuselage in this position.

**6.21.** Install the rudder post temporarily and hold it with masking tape.

**6.22.** Set stab horizontal alignment by triangulation using a measuring device and T pins. Measure from the front of the fuselage to the stab tips. Adjust the stab back and forth until the lengths are within 1/64" of each other.



Squaring And Triangulating Horizontal Stab

Then set the stab vertical alignment. Begin by roughly setting the stab incidence angle as noted on the plans. Install the wing in the airplane. Adjust the wing so it is absolutely parallel with your table top or work surface. Once all is level, secure the fuselage and wing in place. Then measure up from the table top or supporting surface to each stab tip. Adjust the stab to make sure these dimensions are also within 1/64". *When you're done with the measurements, step back and look at everything with your eye.* If it

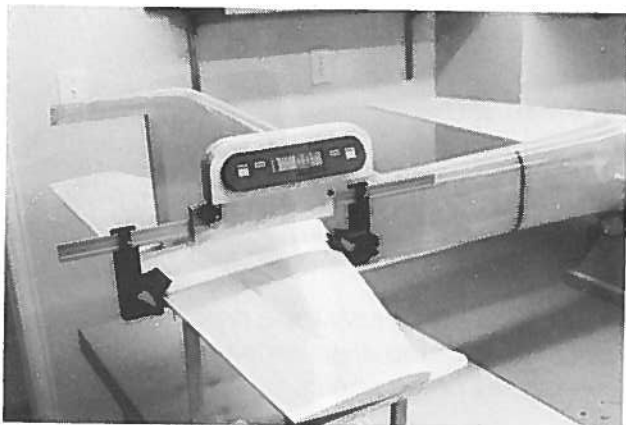
doesn't look right, it probably isn't. Check your dimensions to find out why.

**6.23.** When you're satisfied the alignment is correct, carefully remove the rudder post and tack glue the internal stab phenolic tube and supports to the fuselage with dabs of thick CA adhesive.

**6.24.** Temporarily re-install the rudder post with tape. Check the stab alignment again by measuring, as noted above.

**6.25.** When everything has been tack glued in place, reposition the airplane in the cradle right side up now.

**6.26.** Now the stab has been secured vertically and horizontally. What remains is to secure the incidence of the stab. Using an incidence meter, set each stab panel to the proper incidence noted on the plans. Remove the rudder post and slide the anti-rotation pin reinforcement plates you fabricated out of 1/8" plywood over the anti-rotation pins and press them firmly against the fuselage. (This takes some effort. You're working through the rudder post opening. We use a stick, and lightly tack glue the plate to the stick.) Then slide the stick in and place the plate over the pin. Once in place, break the tack glue joint by twisting the stick, then remove the stick. Using thick-set CA glue tack glue them in place. Again we use a stick. Dab CA on the end and drop the CA on the joint between the fuselage and plate.



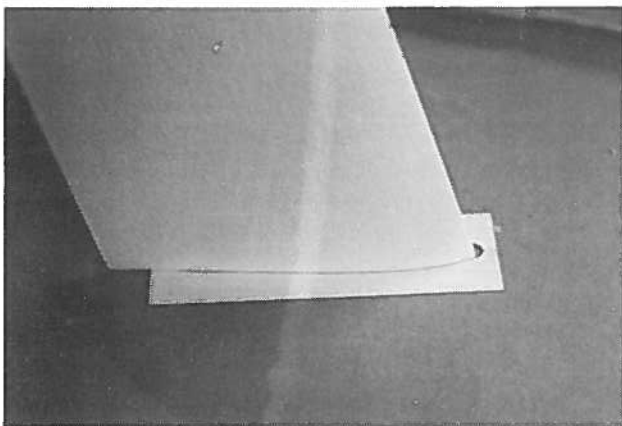
Setting Incidence Of Horizontal Stab

**6.27.** Temporarily install the rudder post and again check all the alignment dimensions. When all is correct, glue all the components permanently in place using thin CA.

**6.28.** The stab halves may be held in place by a 4-40 machine screw, or an equivalent sheet metal screw, installed approximately halfway out of the tube on the bottom side of each stab half.

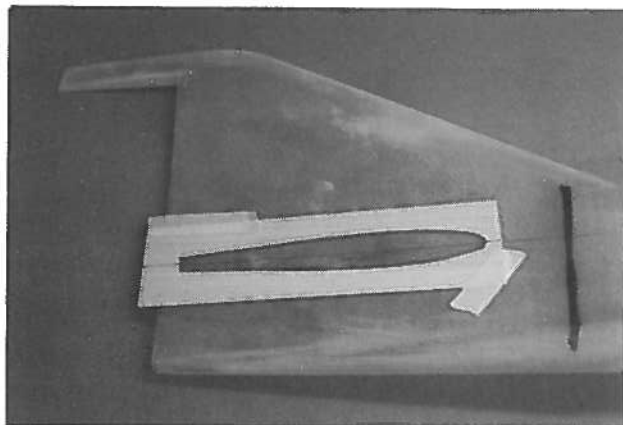
#### HORIZONTAL STABILIZER: FIXED

**6.29.** Begin the installation of a fixed horizontal stabilizer by tracing the root of the stab core on a piece of scrap 1/16" balsa wood. Remember to allow for the thickness of the sheeting. What you're doing is creating a template to cut material from the fuselage.



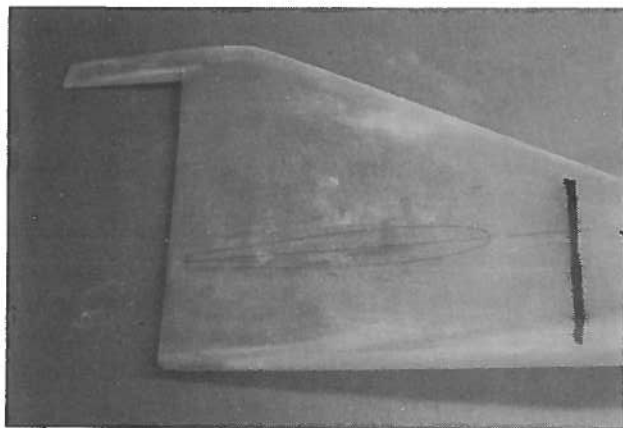
Stab Outline Traced For Balsa Template

**6.30.** Draw the appropriate centerlines for the stab on the fuselage as per the plans furnished with the kit. Position the template over the centerline drawn on the fuselage and tape it in place.



Template Taped On Fuselage On Horizontal Stab Centerline

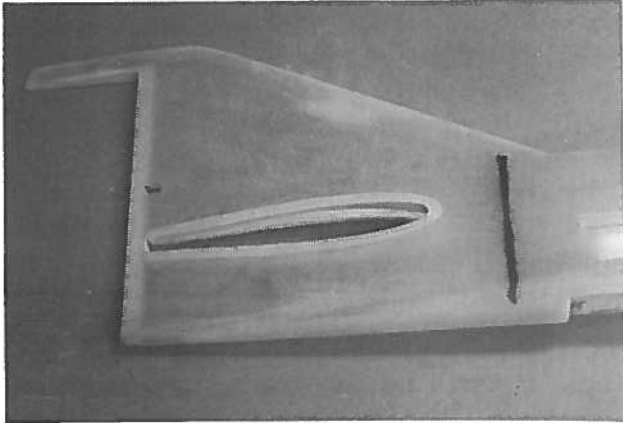
**6.31.** Trace the outline of the template on the fuselage.



Outline Of Stab Traced On Fuselage

**6.32.** Remove the fiberglass from the fuselage using the outline of the template marks as a guide. Take the template and trace the outline on two pieces of 1/4" balsa wood. On the outside of the template line draw another line approximately 1/4" out from the template line. Cut the piece from the 1/4" balsa. Place each piece inside the fuselage and glue it in place with either epoxy or CA adhesive. *You have now created an opening for the stab in the fuselage.* The balsa pieces give the stab more area to attach to the fuselage. This is important because the fuselage is very

thin and does not allow much gluing area for the stab installation. The extra balsa adds rigidity and strength to the joint between the fuselage and the stab.



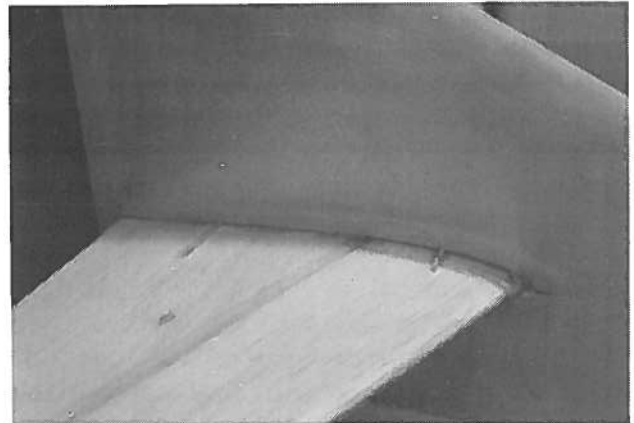
Balsa Filler Inside Fuselage Around Horizontal Stab Opening

**6.33.** Construct the stab as detailed in the stab construction section. Glue the two halves together, making sure the airfoils at the roots match and the trailing edges of the stabs are exactly straight. Once constructed, slide the stab into the hole in the fuselage. The fit might be tight, so remove material from the fuselage at the appropriate areas. You want some room around the stab, but not a great deal. The room between the fuselage and the stab will be used for adjustment during the final alignment. The stab must be allowed to float in the hole. If there is any binding, the final stab alignment will be off. Once the stab is in the hole, start the alignment process as outlined in, Chapter 6 Alignment.



Checking Horizontal Stab Alignment

**6.34.** To hold the stab in place during the alignment process, use slivers of balsa wood gently wedged between the stab and the fuselage. The secret to a properly aligned stab is to *gently* install the slivers and use a lot of them. Once satisfied with the final alignment, glue the wedges in place with CA glue. Glue next to the fuselage only and not out away from the stab. Once glued, cut the extra portion of the slivers protruding from the fuselage. Check the alignment once again to ensure that nothing has moved. If all is well, form a nice fillet between the stab and fuselage using Evercoat body filler. Sand the fillet smooth and you're finished.



Stab Tack Glued In Place

## RUDDER INSTALLATION

**6.35.** Epoxy the balsa tail post to the fuselage. Hold the assembly in place with strips of masking tape until the glue has cured. Remember to roughen and clean the fiberglass inside the fuselage prior to applying the epoxy.

**6.36.** Temporarily hinge the rudder to the tail post and flare in the bottom of the rudder balsa skins and the lower rib to the fuselage with a sanding block.

## Chapter 7 FINISHING

You have now finished the construction of your pattern airplane. The remaining tasks prior to flying the airplane are finishing and equipment installation. A recommended lightweight finish for your airplane is to paint the fiberglass fuselage, and iron-on film for the balsa-sheeted parts. Most builders are familiar with iron-on film finishes, but have not done much painting.

Painting can be done with a brush, spray cans or elaborate compressor and specialized spray guns. The type of finish you want generally depends on the choice of either spray cans, or a compressor and specialized spray guns. A compressor and specialized spray guns will provide the best results; however, it is important that you learn how to paint. This will allow you to achieve the award-winning finish you want. Without that knowledge, the best equipment will only produce a mess! An explanation of the various facets of painting techniques could easily double the size of this book. Why cover a subject that has been covered very well by many others? For the basics of painting, read *There Are No Secrets*, by Harry Higley. This book covers all facets of finishing. It is written in an easily followed format and is very informative, and covers the basics very well. But it is missing some important hints on masking and covering for trim colors.

Trim colors are applied the same way as the base coat, but require masking and covering to keep the colors where you want them. *First and most important, do not use masking tape to define the edge of your trim color; the paint will run under the tape edge and blur the line.* To accomplish a nice crisp line, use 3M fine line tape, which produces a sharp paint line and will conform to almost any shape. It is available from automotive paint supply stores. Follow their directions; we offer a few simple hints to make it work better.

**7.1.** Do not stretch it when you're applying it to the fuselage. This will stress the tape and allow paint to flow under the edges of the tape.

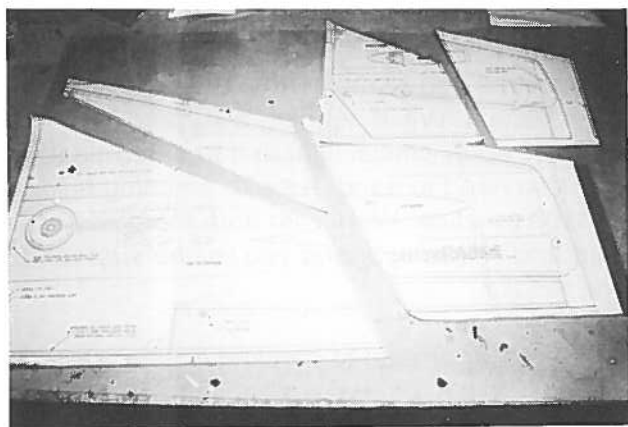
**7.2.** When two pieces of fine line cross over each other, there is a potential for paint to flow into the void of the overlapping piece. To prevent this from happening, run your fingernail over the joint just prior to applying the paint.

**7.3.** After you've masked off your trim color, cover *all* areas that are not to receive paint with painter's masking paper (plain brown paper) and masking tape. If you're going to paint more than one airplane, purchase a masking machine. The machine places the masking tape on the edge of the paper as you extract the paper from the machine. You can purchase one at your local do-it-yourself store; the cost is minimal and the time saved is well worth it. By no means use newspaper to cover areas because solvents in the fresh paint will react with the newsprint and adhere to your fuselage, and you'll have the latest news embossed over the base coat of your fuselage!

**7.4.** After you have applied the trim color clean the equipment and while the paint is still wet, remove the fine line by pulling back on itself. Don't wait until the paint is dry to remove the fine line tape. The paint might stick to the fine line tape and pull off with it. This can result in a lot of additional work and foul words, *especially* after you've sprayed on your best coat of paint!

Everyone who's built a model airplane has worked with iron-on films. They are the choice of many builders. Iron-on film is easy to apply, does not require elaborate equipment, does not spread fumes through the house and (with a little effort and practice), produces excellent results. Again, Harry Higley's book covers the subject quite thoroughly. However, here we offer some hints that have worked well for us over time.

After you establish the trim scheme, make simple full-scale templates from prints of plans adhered to cardboard. The time to do this is made up by not having to measure individual pieces four different times for a symmetrical pattern. We do this for both the horizontal stabs and the wings.



Cardboard Templates For Cutting Covering Material

**7.5.** Seal the gap on the ailerons with Monokote or tape applied to the lower surface. This is critical! *Remember, it is the differential in air pressure over the top and bottom of the wing that allows an airplane to fly.* If you have a gap between your aileron and wing, the air pressure between the two surfaces is compromised and the ailerons become less effective. Do not consider your airplane finished or covered until you seal the flying surfaces. We used to think this was a lot of nonsense until we tried it--it makes a difference. It is also important to apply the film *prior* to flying the airplane for the sealer to remain closing the gap. We have never been able to clean the area around the gap thoroughly enough to allow the sealer to stick *after* we flew the airplane. So, for the longevity of the sealer, apply it before you fly it. Also, sealing the gaps helps the trimming process by making both wings and stab halves aerodynamically equal.

## USING SANDPAPER

*Using sandpaper properly is as important as choosing the proper sandpaper.* We don't like to sand anymore than anyone else. However, sanding is essential to a first-class finish on your

airplane. If you take the time to sand all imperfections out of the model, a major portion of the battle to achieve a quality finish is over. But if you use sandpaper improperly, no matter how good the final finish is, all the minor imperfections underneath will be visible.

Sanding creates dust. Dust is bad for your lungs so use a respirator.

You shouldn't have to work very hard to remove material or finish a surface. If you are applying a lot of pressure to the sandpaper and block while sanding, something is wrong. Either you are using too fine a grit of sandpaper or the sandpaper is worn out.

Choose the correct grit of sandpaper to accomplish the task at hand. Have a minimum of four or five sheets of various grits of sandpaper available. We always have a few sheets of 100, 220, 320, 400, 600, 1000 and 2000 grit silicone-carbide sandpaper available; 150, 220 grit garnet sandpaper, and 100 grit aluminum-oxide sandpaper. If in doubt, always error on the side of "too fine" a grit of sandpaper. Nothing is worse than putting deep gouges in a surface because you choose "too coarse" a grit of sandpaper. If you are sanding, and nothing is happening, then choose a lower grit and try again. You will develop a feel for the proper combination of grit and pressure for a particular task. Again, this all depends upon the surface you're sanding. How you rough sand and shape a big block of balsa with 80 grit is totally different than when you are removing dust and light orange peel from a painted, clear-coat finish with 2000 grit.

Don't be a miser with the sandpaper. We admit that sandpaper is costly. At \$1.00 for a 5-1/2" x 8-1/2" piece of 2000 grit, sandpaper isn't cheap. However, your time is also valuable. When the sandpaper is loaded up with junk or the grit is worn out, throw it away. If you're as tight as we are, it's difficult. *But a new piece of sandpaper is about as much fun to use as flying in calm air!* Anyway, who wants to spend time sanding when

they could be flying? One technique we use to extend the life of sandpaper is to “spank” it. When the sandpaper is loaded with debris, take a flexible metal ruler and slap the sandpaper sharply a few times. Hold the sandpaper at arms-length though, because the dust will fly. After you have done this a few times you will notice the grit remains loaded and is getting dull ... time to replace the sandpaper.

Use the proper technique when sanding rounded surfaces. Don't sand parallel to the axis of the curve, or you'll develop flat spots. Sand a 45° angle to the axis of the curve in long strokes. This will ensure a nice continuously round surface without flat spots.

Don't use water or a wet sanding technique on balsa wood. Sanding balsa with water makes a mess of both the sandpaper and the balsa. You also run the risk of warping the balsa. Apply a simple rule: Wet sanding works great on waterproof surfaces like fiberglass. The idea of the water is to keep the sandpaper from loading up. The water acts as a sandpaper cleaner. The excess material from the sanding process is suspended in the film of water and is kept away from the sandpaper grit. Consequently, the grit stays clean. Usually a wet sanding technique is used in conjunction with close-coat fine-grit sandpaper used for finishing the airplane. Wet sanding makes a mess. *Make sure you are working in an area that you can easily clean when you are done.* When sanding, constantly dip the sandpaper into a container of water. Examine the sandpaper to ensure it isn't loading up. If it is, toss it and get another piece. Have a wet sponge handy and constantly wipe off the sanded surfaces. Examine the sanded surface constantly. At this point in the finish process it takes very little to sand too much. As the old saying goes, “Make haste slowly.”

“Critical light” and a piece of old T-shirt are excellent tools to identify deficient areas needing sanding. After sanding a surface (to what you think is) smooth, hold the T-shirt between your fingertips and the prepared surface and stroke it.

You'll be surprised at how you can feel the imperfections. Critical light (light that falls at a low angle to a surface and shows imperfections by shadows) will also help you find flaws in a finish surface. Hold a surface close to an incandescent light at a very low angle to your line of sight. This is similar to looking down the side of a car with your eye very close to the surface. If done properly, all kinds of imperfections appear as shadows. Use this light to your benefit. While sanding a surface, constantly apply critical light to it to determine where you need to sand. As with anything else, this takes practice. *Work with both the piece of T-shirt and critical light and you will be surprised at the results.*

Your mental approach to sanding is very important. Once you realize that sanding properly will produce a top-quality finish, you will be encouraged to do a good job. The more you work on your sanding technique the easier and more fun it will become.

The secret to sanding is to use a respirator, the proper grit sandpaper, sanding block, technique, to go slowly, have a good mental approach and to have a lot of patience. If you apply these principles, you won't agonize over the sanding process and just might learn to enjoy it.

## SANDPAPER BASICS

The type and size of the abrasive, the density of the abrasive and the backing material classify sandpaper. Sandpaper is manufactured from a myriad of abrasive materials. The following is a list of the most common abrasives:

- Flint;
- Garnet;
- Aluminum Oxide;
- Silicone Carbide.

The grit, or size, of sandpaper abrasives ranges from 16 to 2000. The grit is first ground from large chunks of either man made or natural material. The grit is then passed through a

series of sieves. Grit-size is determined by the size of grain that is contained on a particular sieve. Grit-size determines the coarseness of the sandpaper. The grit-size is noted on the back of the sandpaper. The lower the number of the sandpaper grit, the courser the sandpaper. You would use an 80 grit sandpaper to do rough shaping of a component. A 2000 grit paper would be used to remove dust particles from a clear coat paint finish. The backing material for sandpaper can be a simple paper product, a waterproof backing or cloth.

Sandpaper is also categorized by the coat, or density, of the grit. The density comes in either "open" or "closed." The grit on an open coat paper covers well over half the paper; closed coat covers even more of the paper. We prefer the open coat for working on balsa and closed coat for wet sanding of painted surfaces. The back of the sandpaper will state if it is a closed or open coat paper.

## TYPES OF SANDPAPER

*The proper choice of sandpaper will make a big difference in the time spent sanding and the finish product quality.* The following is an explanation of the different types of sandpaper most widely used.

### Flint:

Flint sandpaper has been around for many years. It is made from natural stone; it is inexpensive and doesn't last long. As a modeler, this should *not* be your first choice for sandpaper.

### Garnet:

Garnet sandpaper is widely utilized in the woodworking industry. The grit sizes range from 40 and up. The lower grits are used for removing large quantities of wood quickly. It is more durable than flint, but, it is also more costly than flint. This might be your first choice for sandpaper. We use garnet when we are

constructing sheeting. When constructing sheeting, we work with a wet adhesive at the joints and then sand the surrounding area to create a dust filler for small voids and cracks in the sheeting joints. We're not concerned with durability because the sandpaper will clog with adhesive and balsa dust before it wears out. Garnet sandpaper can't be used for wet sanding because adhesive and backing of the sandpaper will disintegrate if it gets damp or wet.

### Aluminum-Oxide:

Aluminum-oxide is manufactured from a man-made grit. It is very durable and more expensive than garnet. Aluminum-oxide is a softer grit than silicone-carbide. Aluminum-oxide sandpaper is used primarily for wood. It comes in a wide range of grits.

### Silicone-Carbide:

Silicone-carbide is also manufactured from a man-made grit. The grit is harder than aluminum-oxide and is used for sanding glass, marble and stone. It is also expensive and durable. Although it is expensive, it is our first choice for sandpaper. It cuts fast and the backing is very flexible. We use the lower grits to remove and rough-shape large blocks of balsa. We use the higher grits to finish sheeting and primer. It can also be used for wet sanding.

## SANDING BLOCKS

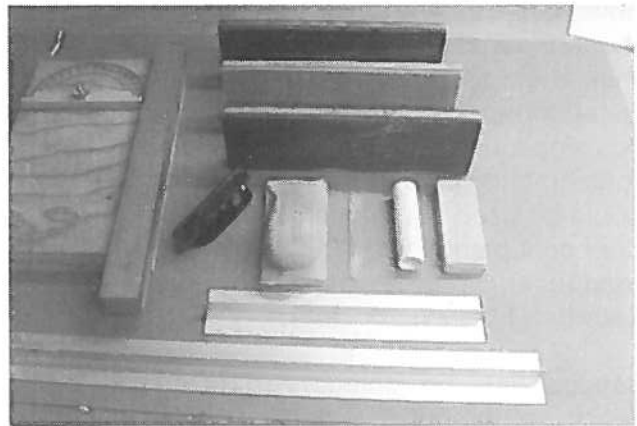
Sanding blocks are of paramount importance. Using your hand to sand is not advised since your hand can't maintain a nice, rigid substrate for the sandpaper. Subsequently, the sandpaper cuts unevenly and the sanded surface will be riddled with ripples and dimples. We highly recommend building cheap sanding blocks from common lumber yard wood. We use D-select 1"x4" pine and cut it to the length of the sandpaper we're using. There are two methods of attaching sandpaper to a 1"x4" sanding block:

1. Router a groove in the edge of the block approximately  $5/16 \times 5/16$ " square, then cut a spline approximately  $1/4 \times 1/4$ ." We begin wrapping the sandpaper around the block by inserting a long edge in the groove and wrapping it around the block until the other long edge ends up in the groove. We then insert the spline into the groove to hold the sandpaper.

2. Use simple thumb tacks (see the Sig Balsa section in Appendix A for a view of this technique).

We have fabricated three blocks to hold three different grits of sandpaper. In addition to the large wood sanding blocks, we use a  $1 \times 2 \times 4$ " wood block for areas requiring a smaller sanding block. This size is ideal for a  $1/4$ " piece of sandpaper. We also use two types of sponge sanding blocks, which can be obtained from an automotive finish store. One block is contoured to your hand and utilizes a strip of adhesive-backed sandpaper, named "3M, Stickit, Soft Hand Block," part number 05442. We use this sponge block with 180 grit silicone-carbide sandpaper after completing the rough sanding. This sponge block is the handiest sanding instrument available. As usual, the block and sandpaper is expensive. The block is about \$6.00, and a roll of 180 grit adhesive-backed sandpaper is about \$27.00. (Those auto finish stores are real proud of their products!). The other sponge block we use is a  $3/8 \times 2 \times 1/2 \times 5 \times 1/4$ " rectangle. We use this block to sand the paint and primer finishes on fiberglass parts. The last two blocks we use are "T-bar" sanders. We have a 24" and a 12". Are you ready to hear about some of the goofy sanding blocks we use? How about various diameters of PVC pipes and wood dowels in  $5 \times 1/4$ " lengths? Wrap sandpaper around the pipe and work those round areas. Use the emery boards your wife, or significant other, uses to sand her nails in those tight areas to square the corners. All these sanding blocks might sound like a lot of muss and fuss, but each one has its individual use. How we use a particular block might be totally different than how someone else uses it. As you

develop your sanding skill, you too will develop a cache of instruments.



Various Sanding Blocks

## PAINTING

### Safety

Spraying paint is dangerous! The process must be respected. The airborne paint particles and fumes, if inhaled into your lungs, can be detrimental to your health. In addition, the airborne paint particles and fumes are extremely flammable because of the solvents present in paint. Obviously, explosions near you aren't very healthy for you, either. Therefore, **BE VERY CAREFUL WHEN SPRAYING PAINT.** *With some precautions you can minimize your exposure to danger, but safety must be the paramount issue when spraying paint.*

### Safety Points To Keep In Mind:

- Don't spray paint around open flames;
- Use a simple Tyvek™ spray suit to protect your skin;
- Paint in a properly ventilated area;
- Don't smoke.

## Face Mask

Face Respirators with cartridges that filter out paint fumes are a necessity. Don't expect a dust mask to fully protect you. It's the chemical fumes combined with the airborne paint particles that cause the most problems. Therefore, it is extremely important to:

- Obtain the proper respirator for the project. This could be anything from a nose and mouth respirator to a supplied-air face mask. The painting system will dictate what protection you will need. When purchasing a respirator/face mask, take the manufacturers safety data specifications for the paint system you will be using with you. The salesman can match the cartridges you will need to the painting system you're using.
- Make sure the respirator/face mask properly fits to your face by a competent respirator technician. It does you no good to have the best face mask, supplied air, and the proper cartridges and then have a gap between your face and the face mask that allows fumes to directly enter your nose and mouth.

## EQUIPMENT

The function of the spray gun and the air compressor is to atomize liquid paint. This is accomplished by drawing liquid paint from a reservoir into a compressed air stream. The compressed air stream breaks the liquid paint into tiny droplets, and conveys the now-atomized paint to the desired surface. Once the small droplets of paint reach the surface, they flow together and form a nice smooth film of paint. It sounds simple, but there are a multitude of variables that enter into this simple process to complicate the issue. We'll start by describing the equipment.

## Spray Gun

There are various types of spray guns available. We recommend two types. The trim paint gun and, as an option, an air brush. Spray paint guns are categorized by the way they atomize paint. Because this book is directed towards novice pattern airplane builders, we don't want to complicate the issue by going into a long explanation about the types of guns available. However, we recommend, and most all modelers use, an external mix, siphon-feed gun. These guns draw paint from their liquid reservoirs using suction and then atomize the paint as it leaves the gun. If you are just getting started and funds are scarce, look for the Buffalo Trim Gun. This one costs approximately \$30-\$35, is similar to more expensive guns (without the superior quality of the higher priced guns, of course) and is a good value for the beginning painter. We have successfully painted many airplanes with this simple, inexpensive trim gun. As your knowledge and skill increases and you believe you can achieve better quality finishes with better equipment, then consider using the more expensive spray guns.

As your painting technique improves and you want to do some "trick" painting, look into air brushes. These spray guns hold a small amount of paint which is directed at a very concentrated area, just like a paintbrush. They work well to dress up your airplane and add a little flair to it. But again, this is a little advanced and the beginner should consider only a trim gun to start.

## Compressor

You need an air compressor that will deliver 40 psi pressure at the volume of air necessary for a trim gun. Most hobby compressors won't meet this criterion. If you plan on using a hobby compressor, be forewarned that you might experience problems with running and splattering paint. If you can afford a larger compressor, buy it. An air compressor is one of the handiest machines in our building shops. In addition to painting, we use the compressed air

to clean balsa dust off wing and stab panels when we are Monokoting, drying engine parts after they have been cleaned, and blow debris out of small ports in the engine. If, however, funds are low, consider renting an air compressor from a local rental store. But if you do, you should also get a regulator, air dryer, a reasonable length of hose and various air hose fittings.

### Regulators And Air Dryers

A regulator and an air dryer are musts! These two items will remove, or help you remove, a majority of the problems associated with spraying paint. They are relatively inexpensive. The regulator controls the pressure of the compressed air delivered to the spray gun. It is very important to have a constant flow of compressed air to the spray gun, because without it, the paint will splatter and run or dry out before it hits the model surface. An air dryer is necessary because it removes moisture from the compressed air stream. As air is compressed its density increases and moisture present in the air prior to compression is condensed out; the air dryer removes and prevents moisture-related problems with your finish.

### HOSE AND FITTINGS

You also need to purchase a length of hose and the proper air fittings. You will need a sufficient length of hose to connect the air compressor and spray gun and to give you sufficient length to be able to work around your model. Remember to get the correct hose diameter for your application; the standard is 3/8" diameter. But, check yours to ensure you have the correct size. *It is handy to have a quick disconnect connection on the other end of the hose (the spray gun end).* We don't know what we would do without one. During the painting process we are constantly connecting and disconnecting the compressed air supply to the spray gun. Without a quick disconnect, you will constantly have the spray gun attached to the air hose, which is extremely inconvenient.

## MATERIALS

### Fiberglass

If you're working on a pattern airplane you are, most likely, working with fiberglass or balsa wood as a substrate for your finish. The balsa wood components require a few more additional steps to the finishing process than fiberglass components. You must first fill and seal the balsa wood so that it will accept a painting finish system. The most common material used to fill and seal balsa wood is a combination of fiberglass cloth and epoxy resin. Combined, these two materials form a nice base for primer/filler. On smaller parts, thin CA can be substituted for epoxy.

The best fiberglass material we have found to apply to balsa wood is Feather Lite Glass Cloth, distributed and sold by Gator R/C Products, Inc. This glass cloth, combined with a thinned, 30-minute epoxy, produces a superior substrate for painting.

Use Dave Brown's or Bob Smith's epoxy in conjunction with the Feather Lite Glass cloth to achieve the lightest finish; however, it is important to thin the epoxy with acetone. The process will be explained in depth later.

### Filler-Primer

The purpose of filler/primer is to fill in the very small voids in the balsa wood, the weave in the fiberglass cloth and to form a substrate for paint. The filler/primer is applied to the fiberglassed parts and then sanded down to produce a smooth finish. It is a misconception that filler/primer or paint will fill or puddle into voids. The paint or filler/primer follows the contour of the void, consequently the void is not filled and still remains. However when the filler/primer is sanded off, the surface around a void is lowered to the top of a void and the void is then filled. If the voids are large, more coats of filler/primer and sanding will be required.

There are as many types of filler/primers as there are painting systems and manufacturers. The most important point to remember is to ensure the whole painting system is compatible from the filling media to the final clear coat. To ensure you have attained compatibility, consult your painting supplier. Ask questions. *We have found that if you tell a salesman that you're painting model airplanes they become enthusiastic about your project.* (We think it's the KID in all of us no matter what occupation your in.)

## Paint

There are many painting systems to choose from when painting your airplane. We recommend three systems:

- Acrylic Lacquer;
- Epoxy Enamels;
- Polyurethane Enamels.

These three are the most widely used and two out of the three are very fuel-proof. There are other paint systems to choose from. But, if you are just starting, keep it simple and choose one of the three we've listed.

Acrylic lacquer is an extremely fast-drying paint. By the time you have cleaned the spray gun and stripped the airplane of the masking tape and paper you are ready to start masking for the next color. Applying acrylic lacquers to airplanes will require a clear coat. Some of the acrylic lacquer clear coats are not fuel-proof. Be careful to choose the correct clear coat to ensure your airplane is protected.

Epoxy enamels are extremely durable and fuel resistant. These painting systems can be found in your local hobby shops, with brand names like K&B Superpoxy and Hobbypoxy. These paints are slow-drying and will take at least overnight to cure before attempting to begin masking for the next color. They come in a variety of colors, but these sometimes don't match the plastic, shrink-covering products. They are reasonably easy to

apply (and also easy to run). Again, that they are extremely fuel-proof is their strongest attribute.

Polyurethane enamels are becoming very popular. These enamels are widely used in the automotive repair industry and are readily available in a myriad of colors. Paint shops can mix and match any color you want. The paint is easy to apply, flows nicely and dries very quickly. The paint is very light, but the clear coat required, if applied unsparingly, can add a great deal of weight to your airplane. The big drawback to these paints is their fumes. You must be very careful applying them. These are the paints that, inhaled only once, can cause your body extensive damage and possibly death. These paints are not to be taken lightly. It has been stressed before and we will stress it again: *Be very careful when using these paints.* If you are just beginning to paint, steer clear of these or have an expert apply them for you. If you do plan on using polyurethane enamels obtain the manufacturer's safety data specification sheets and study them. Do whatever the instructions recommend. It's for your own good.

## Lacquer Thinner Or Reducer

Every painting system utilizes a reducer or thinner. These products allow the paint to be applied. Once on the finished surface, the reducer evaporates along with some other solvents in the paint. The important point to remember is compatibility (we know, we've said this before). Make sure the reducer or thinner you use is compatible with the paint you plan to use. *Mixing the wrong chemicals can cause quite an expensive mess.* If you use epoxy enamel, you must use the thinner/reducer that is compatible with the painting system. Lacquer thinner and epoxy enamel thinner are not compatible. This also applies to cleaning your spray gun. If you clean your gun with lacquer thinner after using epoxy enamel, you run the risk of ruining it by having paint remain and eventually dry in the gun. Clean the spray gun

with the proper thinner or reducer for the painting system you're using.

## METHODS

### Surface Preparation

We cannot emphasize enough the importance of surface preparation prior to painting. The quality of your final product depends upon how you prepare the balsa wood prior to applying the finish. Yes, minor scratches and dings can be covered and filled with primer/filler. But the balsa should be sanded and filled as though there were to be no other finish applied. If you take the time to fill and sand the balsa prior to applying fiberglass cloth and epoxy, you will be able to apply the painting finish quicker and at a higher quality. The filling materials we recommend are Evercoat Body Filler or light weight epoxy filler.

Avoid using the balsa fillers that resemble balsa wood. It has been our experience that these balsa fillers will break loose of their bond with balsa in the presence of paint solvents. Granted, the entire balsa surface is covered with epoxy and fiberglass. However, we have had the material break loose and then create more problems than it solves. The body fillers and epoxies are impervious to paint solvents and, although slightly heavier, will adhere to the balsa, resulting in a nice finish. Once any filler is applied it is important that the surface is absolutely smooth and ready for paint. The secret to surface preparation and painting is to identify your blemishes and imperfections as you continue to apply the finish. This is done using a light source and the "critical light" method of detecting imperfections. The critical light method is discussed in the Sanding chapter.

Remember, sanding is the most critical finishing procedure. When sanding anything, from sealers/primers to the final clear coat, it's important to use a sanding block, be patient and use a wet sanding technique.

### Base Material Application

It is important to apply a base material to bare balsa wood prior to applying a paint finish. The most common base material used for our model airplanes is fiberglass cloth adhered to the balsa with epoxy. This forms a substrate that can be easily filled with primer/sealer and will help produce a beautiful final product. But this can add excessive weight to the airplane. The following procedure will result in a very lightweight system. The important point to remember is not to lose control of the total thickness of the system. Each step of this process is designed to just fill the weave of the fiberglass fabric. Any additional material added will result in added weight and it won't add to the quality of the final, finished product. The weave of the fabric should just show through after the process is complete. However, you must cover each area of bare balsa wood with fiberglass and epoxy. If you don't, the paint finish will simply peel off bare balsa wood.

Begin by sanding the entire airplane with a medium grit sandpaper. Use a sanding block in conjunction with the appropriate sandpaper. It is better to have a flat surface with a few scratches using a sanding block than a smooth but wavy surface without a sanding block.

Don't use thin finishing resins to bond the fiberglass cloth to the balsa wood. Use a slow cure epoxy, such as Dave Brown Mix-a-Matic, thinned 50/50 with acetone to adhere the glass cloth to the model. The slow cure epoxy and acetone mixture is viscous. Upon application the acetone evaporates quickly and the remaining epoxy stays in the weave of the cloth and doesn't penetrate deeply into the wood. Thin finishing resins stay in the weave of the fabric and then penetrate deeper into the wood, consequently adding more weight to the finishing system. To start with, mix only about one ounce of epoxy (the total of both parts A & B). After thoroughly mixing the epoxy, add one ounce of acetone. This mixture will be water-thin. Don't be concerned, -- the acetone will

evaporate very fast and leave the epoxy in the weave of the fabric. *Remember to work in a well-ventilated area.*

Cut the glass cloth approximately one inch larger than the area to be covered. Lay the cloth on the surface of the wood and brush the thinned epoxy through the cloth, smoothing the cloth as you go. Use a one inch brush and work the epoxy mix evenly over the entire area you are covering. Cover one side of all the parts of the airplane, control surfaces included, and let it cure thoroughly overnight.

Use a piece of 320 grit paper to trim excess cloth from the model, then repeat the process, covering the other side of the fuselage and the control surfaces. The fuselage can be done in two steps because of the exceptionally good drape quality of the cloth.

When cured, once again trim the excess cloth and lightly sand the glassed surfaces to remove any burrs or rough spots. If you brush the epoxy mixture so it is very thin, as you should, some areas will appear to be almost dry. In this case, a second coat of thinned epoxy should be applied, again working the epoxy mix evenly over the entire area. Allow the second coat to thoroughly cure before final sanding.

Finally, sand all the glassed surfaces very lightly with 600 grit sandpaper. Don't sand through the fiberglass to the balsa wood. After sanding, thoroughly inspect all the glassed areas to ensure there are no areas that show bare balsa. If you do find *ANY* areas that aren't covered with fiberglass, break out the epoxy mix and fiberglass and cover them. *You don't want any bare spots because the primer sealer won't adhere to the bare wood and you will end up with a big blemish in your final finish.*

### Primer/Filler

Primer/filler is the foundation of your paint finish. Apply it to the fiberglass base. Use the primer/filler to fill the voids in the fiberglass

weave, sandpaper scratches and very small voids. Understand that neither paint nor primer/filler will fill voids. Instead, it will actually flow into and adhere to the *sides* of the voids, accentuating the voids. To remove the voids and sandpaper marks, apply the primer/sealer, wait for it to dry and then sand it off. This will decrease the primer/sealer thickness around a void while leaving some of the primer/sealer in the void. By repeating this process a few times, you will eventually fill the voids. *The application and sanding of the primer/sealer is the most important step to a good finish for your airplane.* If you take the time to do it right, you can fill all the voids and make the finish as smooth as glass. If you don't take your time to remove the dings and scratches, the final clear coat will literally magnify the imperfections and you will be discouraged with your results.

When it is time to apply the primer/sealer, we use a two-stage approach. First apply the primer/sealer with a brush, which looks absolutely unsightly when done. There are brush marks everywhere. However, a paint brush does a better job of filling voids than a spray application. In addition, you don't over-spray and you use less material. Using 220 grit wet/dry sandpaper and water, sand all the primer off, down to the fiberglass weave. Once all the primer has been removed, check for voids. If there are any, paint on more primer/sealer and repeat the sanding process.

Once satisfied that the surface is free of scratches and voids, spray a coat of primer sealer onto the surface. After curing, sand off this layer of primer/sealer. The final sanding is done with 600 grit wet/dry sandpaper with water. Gently sand down this final coat until the surface is absolutely smooth. Refer to the sanding section, page 52, "Sandpaper Basics." During the sanding process, wipe off the excess paste frequently with a clean sponge and then dry the surface. Using critical light, check for imperfections and sand them out. If you are down to the fiberglass weave and there are still imperfections, repeat the process. Remember,

you are striving for perfection. Finish sanding the primer/sealer with 1000 grit wet/dry sandpaper and water. After this step, the surface will be very smoooooth!

## Masking

Unless your airplane will be only one color, you will have to mask off areas that you don't want painted. Masking is not hard, but there are a few procedures and products that will make it much easier to accomplish the task.

Use any professional masking paper from any do-it-yourself center. Don't use newspaper unless you want to read last months headlines on the side of your fuselage. The solvents in the paint will react with the newspaper and ink and bleed through to the underlying surface.

While at the do-it-yourself center, purchase a relatively expensive hand-held masking machine. These devices cost about \$15-\$20, but are worth their weight in gold. They dispense masking tape onto a roll of brown paper with a serrated edge to cleanly tear it off.

Purchase high quality masking tape at an automotive finish store. The adhesive on cheap tape will react with paint solvents and make a big mess. The more expensive tape you find at automotive finish stores have adhesives formulated to withstand the paint solvents. While at the automotive finish store, don't forget to purchase 3M Fine Line tape, masking tape, which masks off a specific area. This is a great product! It comes in widths. We use the 1/8" width for sharp bends and the 1/4" width for long straight lines.

Now that you have the products, let's go through the masking process. First, lay out the area you wish to mask off. We use a water soluble felt tip marker. However, a marker might leave a permanent mark on your surface, so check it by making a small mark on an inconspicuous spot on your airplane, wait for it to dry and then, with a wet cloth, rub it off. Connect the felt tip marker

dots delineating the area you wish to paint with the 3M Fine Line tape. The secret to putting on this tape is to apply gentle tension and press it down. Stretching it will deform it and cause paint to seep under the edges. At the corners, where pieces of the tape overlap, use your fingernail or another dull implement and push the tape against the adjoining piece to prevent paint from seeping into the little crack formed at the overlap. Once you place the 3M Fine Line tape, use the masking machine and run a piece of paper and tape around the 3M Fine Line tape, leaving about a 1/4" gap between the 3M Fine Line tape and the masking tape/paper system. Continue to apply masking tape and paper everywhere you don't want paint, which is everywhere. Don't leave any area uncovered. Now cover the area between the 3M Fine line and the masking tape/paper with a piece of masking tape. Why not just put the masking tape/paper on the 3M Fine Line? Because, after spraying the area and cleaning your gun, we find that removing the 3M Fine Line tape while the paint is fresh eliminates the possibility of having paint stick to the 3M Fine Line. With this masking technique you can remove the masking tape, then remove the 3M Fine Line and leave the masking paper and tape on the airplane until the paint has dried. Then you can remove the masking tape and paper and if you happen to touch the dry paint with paper or tape it won't create a blemish or problem. Otherwise you have to remove all the masking tape and paper to get to the 3M Fine Line. This can expose the fresh paint to physical damage during the tape and paper removal process.

## Paint Preparation

Paint preparation is the first step to producing an award-winning finish. Paint should be mixed in the proper quantities to cover the area you are painting. It should be mixed and reduced properly in a separate container (not in the gun reservoir) and strained while being poured into the gun reservoir.

*The first paint preparation step is to determine how much paint and reducer you need. Are you painting a small area or clear coating the entire fuselage? More than likely the first time you paint, you will mix too much paint reducer. Think small to begin with, and gauge the amount of paint you will use according to our simple guideline of six to ten ounces of paint/reducer to cover an entire fuselage. Use six ounces of paint for a 60 size fuselage and ten ounces for a large 120 size fuselage. Adjust the amount of paint/reducer needed for trim colors based upon these amounts. Most important, write down how much you mixed and how much was left, take the difference and write down how much it takes to do a particular color. You will be able to gauge the amount of paint you will need after only a few paint applications*

Reducing paint is very important. If the paint is too thick it won't spread properly; too thin (reduced) and the paint will run. Generally, people won't thin their paint enough as opposed to thinning too much. Follow the manufacturer's instructions very carefully. If reduced correctly, the paint will have the consistency of water. An easy way to check this is to let the paint run off the stir stick. If it's too thick, reduce with the proper amount of reducer.

Now that you have determined how much paint/reducer you need, grab a mixing cup. No, not the gun reservoir! Paint should be mixed and stirred in a separate *clean* mixing cup. We use *clean*, empty yogurt containers (always have to be thinking about recycling anything you can!). Pour the appropriate amount of paint and reducer into the cup and thoroughly mix, using a stir stick (sticks can be obtained from your paint supplier for either free or for a very small amount of money.) Once thoroughly mixed, strain the paint. Believe it or not, paint is full of clumps. If these clumps enter your gun two events might take place: The gun might plug up or the paint could splatter. Therefore, strain your paint. Before adding any paint to the gun reservoir make sure that the reservoir is spotless. Wipe it out with a clean rag that has been soaked in

paint reducer. Look at the rag. If there is any paint residue on it, stop and clean the reservoir and gun again. If all is clean, continue. Place the strainer on top of the opening to the gun reservoir. Slowly pour the paint through the strainer into the gun reservoir. Don't attempt to push anything through the strainer. It got hung up in the strainer for a reason. Attach the reservoir to the gun and you're ready to start spraying.

### Spraying Technique

Your spraying technique must become second nature to you. Applying the appropriate amount of paint is critical. If you have to think about your technique, the amount of paint applied will vary, which will result in a mottled finish. The proper technique to use when spraying is as follows: Hold the nozzle of the gun approximately 8" to 12" from the surface and perpendicular to the surface at all times. Begin by moving the gun in a nice smooth stroke. After the gun is moving, squeeze the trigger and begin applying paint to the surface. When you have almost reached the end of your stroke, release the trigger while you continue to move the gun. *The gun should never stop moving while applying paint.* This requires a smooth technique you can develop with practice by filling your gun with gun cleaner or lacquer thinner and spraying it onto a piece of old cardboard or metal. Concentrate on keeping the gun moving in smooth, continuous strokes and with a small amount of overlap from the previous application. The speed you move your gun during the paint strokes varies with the painting material you are applying. However, to give you a benchmark to work from, try moving the gun a little faster than a foot per second. If your fuselage is about five feet long try moving the gun from the nose to the tail in a little more than four seconds. Error on the side of moving the gun too fast, as opposed to moving it too slowly. You can always apply more paint. Yet, it's difficult to take it off if you have runs, drips or errors. Be patient. Spraying technique is not something that is learned by painting just one airplane. It takes a while to develop the correct

technique that allows you to apply paint uniformly, at the correct density and without having it run or "orange peel."

Air pressure is critical to proper paint application. Too much air and you have orange peel. Too little air and the paint splatters out of the gun. *Depending upon the material you are using, vary the pressure to suit your needs. We have found that 40 psi is a good starting pressure.*

You can adjust the spray pattern of most spray guns. Basically, the adjustment is in the width of the pattern. It can be either long and narrow, or a circular pattern. The adjustment is generally found near the outlet nozzle. It adjusts two little jets of air that are directed at a right angle to the discharge of the gun. The more air you add, the more the pattern narrows. Back off the air and the pattern becomes round. We prefer the round circular spray pattern.

One of the techniques we use to reduce the penetration of dust into a fresh coat of paint is the proper rotation of the piece we're painting. You may start painting with the piece upright. But this is wrong for two reasons: First, if you start at the top and the coverage is not quite right, it will be visible to everyone that looks at the part. Second, if you start at the top, you'll end at the top and gravity will allow dust to fall onto your freshly painted surface. Rotate your piece to the upside down position and begin there. If you have some problems when you begin spraying, it won't be as visible. In addition, if you end with the bottom side up, the dust will fall on the bottom and leave the top of the piece void (or at least we hope so) of dust.

While you are painting, constantly examine the painted surface using critical light. Critical light will reveal the imperfections in the fresh paint. If the surface appears dry, spray it again. If an area looks really glossy and thick, don't spray any more paint on that area. If you do, chances are you will end up with an area of thick, runny paint.

## Spray Gun Cleaning And Maintenance Procedures

A clean spray gun is paramount. If your gun isn't clean you will compromise your paint finish. A gun clogged with old paint will produce splatters, runs, uneven cover and a tremendous amount of frustration on the part of the operator. *The best time to clean your gun is immediately after you have finished spraying.* The best way is to clean the gun very thoroughly using the following steps:

1. Empty the excess paint from the reservoir into a disposable container.
2. Clean the reservoir, the bottom of the gun and the paint pick-up tube with paper towels and paint thinner or gun cleaner.
3. Fill the paint reservoir about 1/4 full with paint reducer or gun cleaner. Attach the reservoir to the gun and spray the reducer or cleaner into a rag about one inch from the exit nozzle of the gun. At first the excess paint in the gun will exit the nozzle, but after a short time the liquid will begin to appear clear. Continue spraying until the gun reservoir is empty.
4. Remove the reservoir, and with the remaining cleaner and paper towels, clean the reservoir, gun bottom and pick-up tube again. When all is clean again, fill the paint reservoir about 1/4 full of cleaner or reducer. Attach the reservoir to the gun and again spray the cleaner into a container or rag. Examine the discharge; it should be crystal clear, with no color at all. Continue spraying until the reservoir is empty. Stop frequently and clean the exterior of the gun with the cleaner-soaked rag from the discharge of the gun.
5. Once the discharge is crystal clear and the exterior of the gun is clean, you're finished.
6. Apply oil to the areas noted in the instructions that accompanied the gun.

Disassemble the gun to examine and thoroughly clean all the internal parts of the gun that didn't come clean with the quick-clean process. During this process, be extremely careful not to damage mating surfaces. If you damage a mating surface your gun won't function properly. Guns have very few seals and depend upon metal-to-metal surface contact to maintain the proper suction or pressures. Don't use wires to clean orifices because they can damage them. If your gun orifices are clogged, take the gun to an automotive finish store and ask them for advice on cleaning. Don't take a chance on damaging your gun. After assembly, check the guns function by using some cleaner or reducer just as you did during the quick-clean process.

## RUBBING AND FINAL FINISH

"Rubbing" is a finishing technique used to remove minor blemishes, dust and particles on the surface of the final clear coat. The technique has evolved with technology. In the past, rubbing compound and the heat generated by the friction of rubbing would add luster to the final painted surface. Today, a combination of sandpaper, cutting compounds and an electrical buffer decreases the work and time involved in producing a beautiful finish. However, remember that rubbing addresses only minor blemishes.

### Materials

The materials used for rubbing are a very fine wet/dry sandpaper, a cutting compound, a polishing disk and an automotive polisher. We use a 2000 grit wet/dry sandpaper. Very fine grit sandpaper allows you to work the surface without putting big scratches or gouges into the clear coat. Maguires manufactures superb automotive finish products. We highly recommend using the medium and fine cutting compounds in conjunction with their foam buffing pads. Maguires also manufactures excellent polishes. We use two types: non-silicone and silicone-base polishes. The silicone-base polishes are excellent for finishes that have aged for a month or two. *If you are in a hurry,*

*use a non-silicone base polish to allow the paint surface to continue to outgas and cure.* This is extremely important for the longevity of the paint finish. Check with your *local* independently-owned automotive finish store for these products; you won't find them at a *national* auto parts store.

### Technique

The final process we use to finish our paint finishes is very simple and has produced wonderful results. The process is nothing more than sanding out the imperfections and then smoothing out the marks left from sanding until you apply the mildest of abrasives, polish. We must stress that at this point do *not* rush. Take your time, check your work to ensure you haven't gone too far and enjoy watching your finish really shine.

Begin the process by sanding with wet/dry 2000 grit sandpaper. Using water and a foam sanding pad, lightly sand a very inconspicuous area to get the feel and touch. Once satisfied that you have the operation under control, continue sanding over the affected area, or the entire paint finish. *We find that when you are taking the time to rub the finish, you might as well make it uniform and do the entire paint surface.* Again, go slowly, dip the sandpaper in the water frequently to clean it and form a media to carry away the sanded material from the surface of the paint. Wipe off the surface with a clean soft rag and inspect for imperfections and a uniformly sanded surface. You will know when you have imperfections when you dry the surface. They will jump out at you. However, when there aren't any left, the surface will appear dull. Don't panic! This is the natural progression of the process. Once all of the imperfections are sanded out of the surface, it's time for the cutting compound.

Cutting compound is a liquid abrasive. We use the medium and fine-cutting compounds in conjunction with a foam buffing pad. Done correctly, you will need two foam buffing pads.

Use one buffing pad with only one cutting compound. Mixing the cutting compounds on one foam pad won't segregate the two cutting compound processes and won't give you a deep lustrous finish. Again, we repeat, go slowly. Examine your work closely and frequently wipe off the compound with a soft rag to examine the surface. You don't have much surface to rub, consequently, you won't use much compound. Therefore, don't be afraid to wipe off the compound to expose the surface for examination and reapply more as needed. Once done with the medium cutting compound, clean the painting surface thoroughly with a sponge and plenty of water. Wipe it down with a soft rag and examine the entire surface for imperfections. Repeat the process if necessary. Now repeat the entire process again using the fine cutting compound. Once it's clean, you're ready to apply the polish.

If the surface is less than one month old, don't use a silicone-based polish. But if the surface has aged over a month then you should. The silicone-based polish is a good product and will protect your new finish. It will also give you the final deep luster you seek. The silicone ingredient will not break down like wax can under the heat of sunshine. However, if you have to touch-up the finish, removing the silicone polish is difficult and is required to apply additional paint to the existing polished paint.

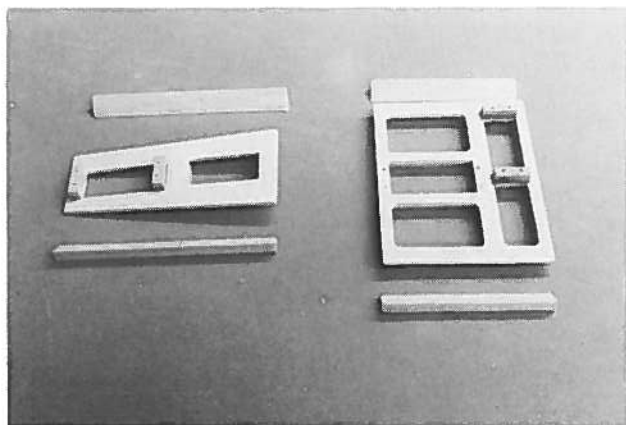
Polishing is the final finishing step. You've worked hard to get to this point. Enjoy the fruits of your labors and take pride in the final product.

## Chapter 8 EQUIPMENT INSTALLATION

### SERVO TRAYS

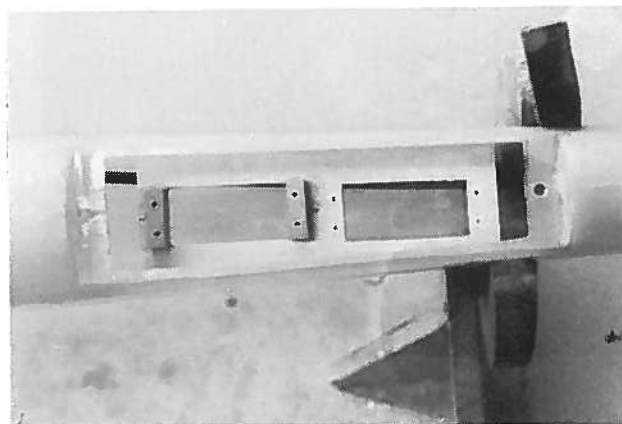
You now have the airframe assembled and ready for finish. However, we recommend installing and removing all your equipment before finishing. Once finished, we don't like to wave it in the air trying to install pushrods, servos, fuel tanks and braces and chancing scratches, dents or banging it into obstacles. If you install the equipment prior to finishing and then remove it, you won't eliminate all of the risk of damaging your finish, but you'll certainly decrease the chances. Also, if during the installation process you dent your wood or put a scratch in the fuselage, it's easier to repair now rather than later.

**8.1.** Start the equipment installation with the servos. Cut a servo tray for the retracts and throttle and another one for the elevator and rudder. Screw the servos to the servo trays in their respective positions.



Front And Rear Servo Trays

**8.2.** With the airframe assembled, lay the servo trays with servos attached in the fuselage at the approximate locations shown on the plan.



Rear Servo Tray Installed

**8.3.** Mark the sides of the fuselage and remove the servos and tray.

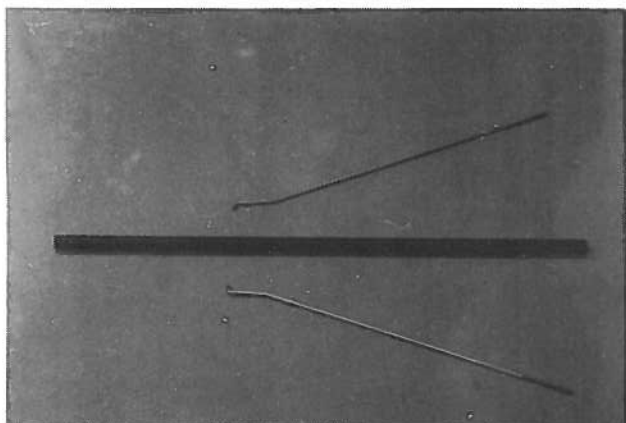
**8.4.** Cut two pieces of triangular stock the length of the servo tray. Apply some RC-56 glue to one side of the triangular stock and place the top edge of the triangular stock against the fuselage side and 1/16" above the line that was drawn on the inside of the fuselage. Once the glue has dried, insert the servos and tray in the fuselage and tack glue them in position.

### ELEVATOR PUSHROD

**8.5.** Fabricate the pushrod for the elevators. The pushrod is constructed from a fiberglass arrow shaft, Dave Brown "Y" end connector, and two 2-56 rods with approximately 1" of thread on one end. Measure the distance from the elevator servo to the tail post. Subtract approximately three inches and cut the fiberglass shaft to this length.

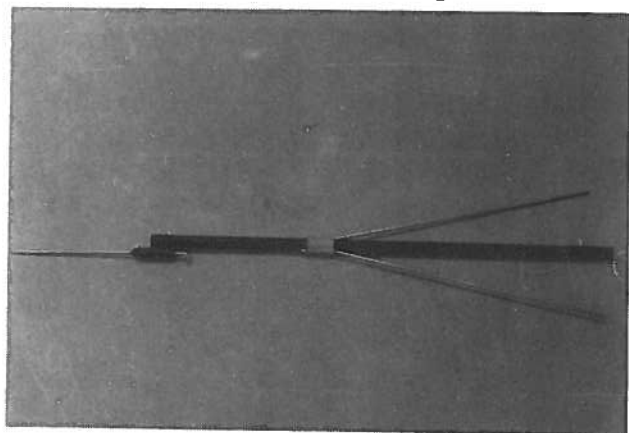
**8.6.** Drill holes in the shaft at the locations shown.

**8.7.** Bend the 2-56 rods to the configuration as shown. Cut off the excess rod.



Pushrod Components

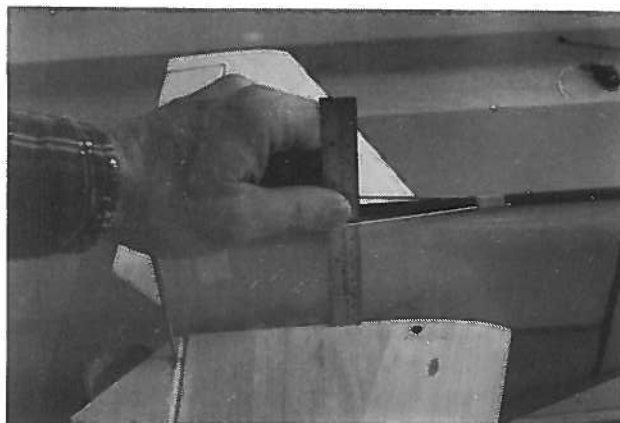
**8.8.** Place the bent rods in the locations shown and wrap heavy carpet thread around the joint. Then secure the thread with CA glue.



Pushrod Wire Rods Wrapped With Carpet Thread

**8.9.** Cut a piece of brass tube approximately 1-1/4". The brass tube should be able to slide smoothly over the fiberglass arrow shaft without binding. This brass tube will hold the end of the arrow shaft at the tail post. Therefore, the tube must be large enough to allow the shaft to slide smoothly without excess movement.

**8.10.** Turn the fuselage (with the horizontal stab and elevators temporarily installed) upside down, and lay the elevator pushrod on the bottom at the location it will be installed inside the fuselage. Mark the intersection of the 2-56 rods and the side of the fuselage.



Locating Pushrod Wire Exits On Fuselage

**8.11.** With horizontal stab and elevators upside down, slide the elevator servo and tray into the fuselage. With a felt tip pen, mark the location of the servo wheel, or arm, on the side of the fuselage.

**8.12.** With the control horn installed in the elevator, run a string from the control horn to the mark on the fuselage for the servo arm or wheel. (This picture also shows the rudder installation).



Locating Exit Of Pushrod Wire Rods

**8.13.** Mark the intersection of the string and the mark previously made for the 2-56 rods. This represents the location where the 2-56 rod will exit the fuselage. Also, mark the location of the string before and after the intersection on the fuselage.

**8.14.** Remove the string and draw a line between the two points going through the intersection.



Establishing Servo And Control Horn Lines

**8.15.** Cut a slot approximately 1-1/4" long centered on the intersection and parallel to the line on the fuselage.

**8.16.** Slide the pushrod into the fuselage and push the 4-40 rods through their respective slots in the sides of the fuselage. Screw a clevis to the ends of the rods and connect the clevis to the control horn on the elevator.

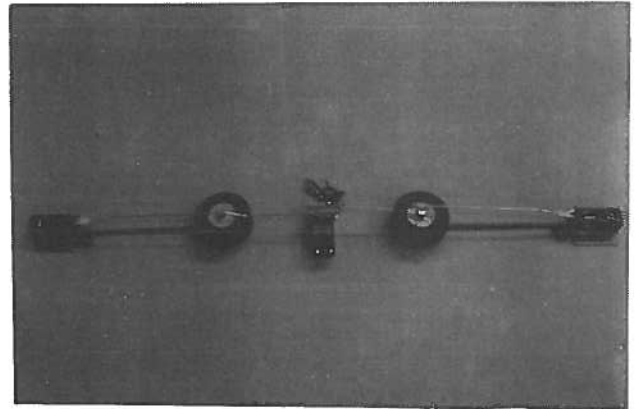
**8.17.** With the wire end on the servo wheel for alignment, push the rod back and forth. Check for binding of the rod against the fuselage and adjust the slot length, if necessary. If the slot becomes too big use the body filler used for the fuselage seam and fill in the excess. The first time we tried this, we just guessed at the locations of the holes. By the time we were done, the rear of the fuselage was covered with body filler - but at least we weren't cutting, patching and touching up the finished product.

**8.18.** Once all fits well, remove the pushrod and servo tray containing the rudder and elevator servos from the fuselage.

## RETRACT LANDING GEAR

**8.19.** We prefer to use the mechanical retract system. The following picture depicts which components are incorporated into the system.

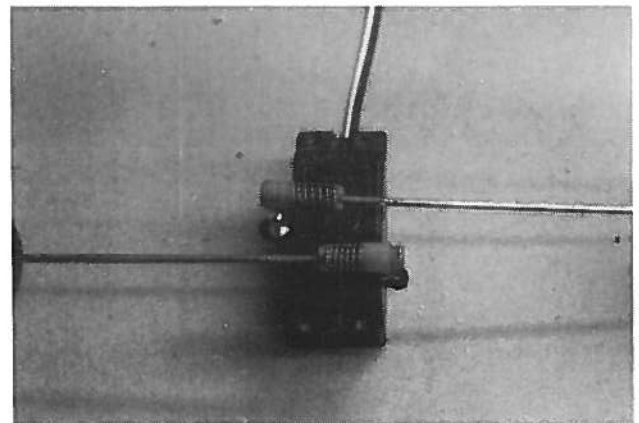
Note the simplicity of this system over an air system.



Mechanical Retract System Components

**8.20.** Install the servo tray containing the retract and engine servo in the airplane. Slide the wings onto the airplane.

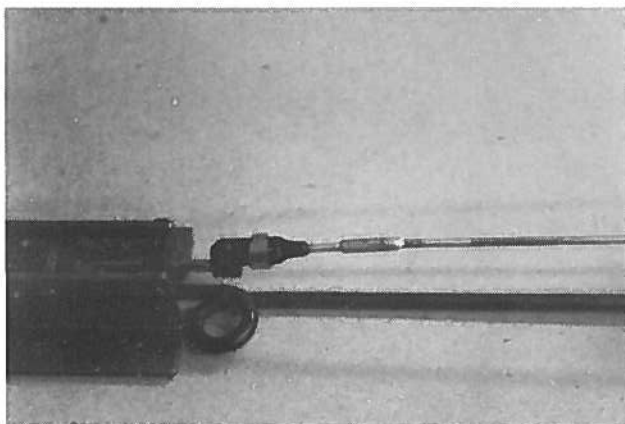
**8.21.** Install a Sullivan quick-link on each threaded end of two 2-56 rods, and the balls on the servo actuating arm (the quick-links make for a fast set-up at the field). Insert the 2-56 rod through slots cut in the fuselage and root area of the wing so that there is no binding of the actuating arms. This might require some creative bending of the actuating arms. Snap the quick-links on the servo actuating arm to engage the retracts. NOTE: The mechanism has been removed from the fuselage for clarity.



Retract Servo With Quick Links Installed

Screw a quick-link on a threaded coupling. Snap the quick-link on the retract actuating

mechanism. Lay the actuating arms over the threaded coupling and mark where to remove the excess 2-56 rod. Remove the actuating rod and threaded coupling/snap link from the airplane. Solder the actuating rod to the threaded coupling. NOTE: The retract has been removed from the wing for clarity.



Pushrod Connection To Retract

**8.22.** Install the retracts in the wings, wings on the airplane, and actuating arm to the servo arm. Rotate the retract servo to the end position, corresponding to the position of the landing gears (i.e. if the gear is down, position the servo in the down position). Adjust the actuating arm to the proper length with the snap link. Once you've made this adjustment the retract system is virtually maintenance free.

## THROTTLE

**8.23.** Install the servo tray containing the retract and engine servo in the airplane.

**8.24.** Slide a piece of Nyrod housing through the hole in the firewall you previously drilled for the throttle control. Position the end closest to the engine servo approximately 2" from the servo arm. Cut the remaining housing back approximately 1/8" from the firewall.



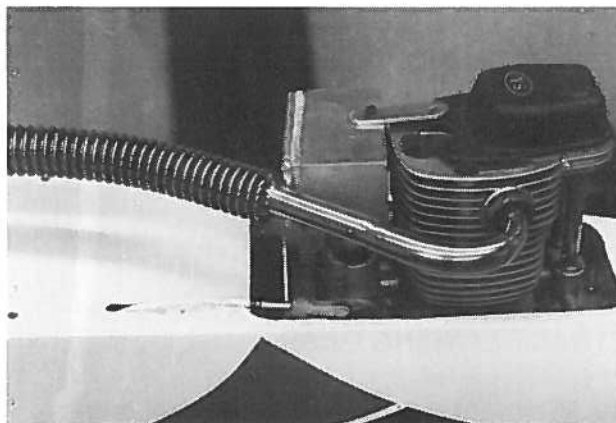
Throttle Cable Installation



Stand-Offs For Throttle Cable Installation

**8.25.** Install the engine.

**8.26.** Slide a piece of cable inside the housing and screw a clevis to the engine end of the Nyrod. Connect the clevis to the engine throttle arm.



Throttle Cable Connection At Engine

**8.27.** Install a Dubro EZ connector on the wheel and slide the cable through the connector. Then install the wheel on the servo. Install the servo and set it for "no throttle" and "no idle." Pull the cable back against the carburetor stop screw again. Mark the cable where the cable and servo arm hole intersect. Once you've established the length, cut off the excess.

### MUFFLED PIPE EXHAUST SYSTEM

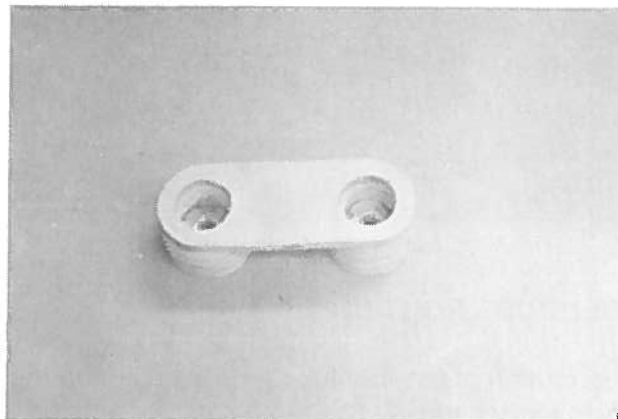
The latest trend in exhaust systems for 120-four stroke engines is the muffled pipe exhaust system. The 60-size engines depend upon a specific length for the tuned pipe exhaust system to function properly. However, the 120-engine exhaust system is much simpler because it doesn't depend upon a specific length to function properly. The drawback to using a four-stroke engine in lieu of a two-stroke engine is the amount of vibration encountered. The 120-engine and exhaust system should be isolated from the airframe to prolong the life of the airplane. Isolating the engine and exhaust system appreciably decreases the vibration transmitted into the airframe, prolonging the life of the airframe and components. We have been successful using the AAP muffled pipe system. Most of the hardware for installing and isolating the pipe are included when you purchase the pipe. Only the header clamp and isolator are not included with the pipe. However, the isolators are readily available and you can easily make the clamp.

Once you've installed the firewall in the fuselage, now install the header and pipe. Install the engine in the airplane and connect the header to the engine. Connect the header to the pipe as described in the instructions included with the pipe. The header and pipe should now be lying loose on the bottom of the fuselage.

Following the instructions supplied with the pipe, locate the mounting clamp around the pipe. Center the pipe and locate holes in the bottom of the fuselage for the isolators.

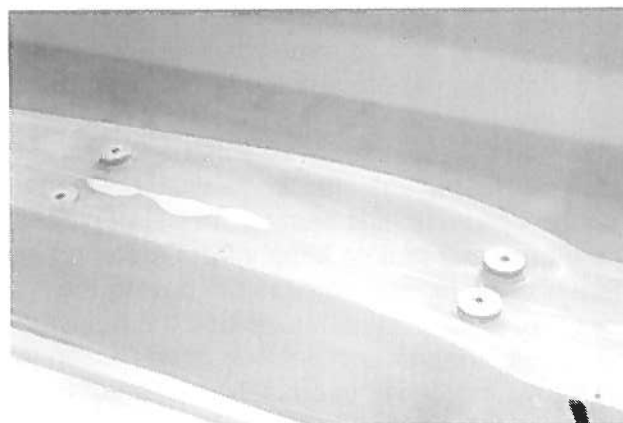
**8.28.** Remove the pipe and drill holes for the isolators.

**8.29.** Back the holes inside the fuselage with a 1/8" plywood bracket. Drill through the plywood. Install blind nuts for the isolators.



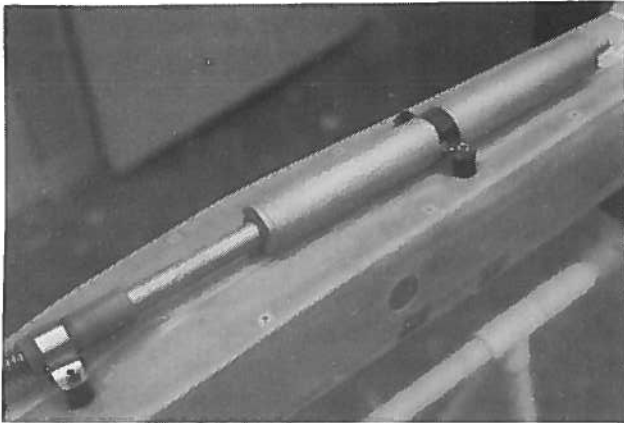
Isolator Mounting Bracket

**8.30.** Install the brackets in the bottom of the fuselage using epoxy. Mix epoxy and microballoons and form a smooth fillet around the base of each support for strength and to seal the bottom of the fuselage.



Brackets Installed In Bottom Of Fuselage With Epoxy Fillets

**8.31.** Install the engine, pipe and isolators. Check to ensure that it all fits properly.



Muffled Pipe And Supports

## FUEL TUBE ROUTING

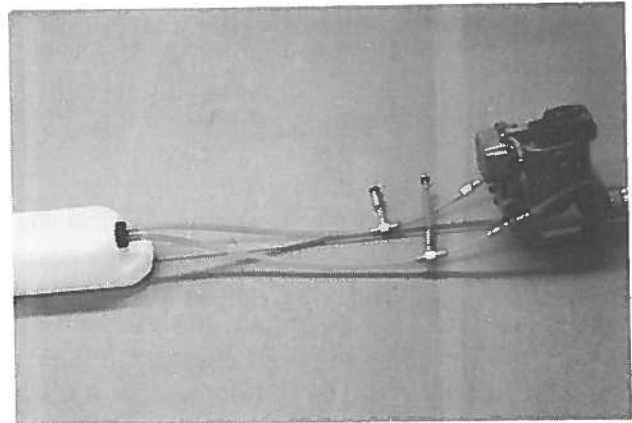
The routing of the fuel tubing depends upon the engine you choose. The most common engine used today is the YS 120. This engine uses crankcase pressure developed during the downstrokes of the piston. The pressure is directed into the tank, then pushes the fuel into the engine. This system ensures an even flow of fuel to the engine at any attitude. There are two problem with the pressurized system: Choosing a fuel tank that won't rupture because of the systems pressure, and remembering to properly fuel the airplane to prevent the "YS nitro bath."

We've had the most success with the Dubro tank. The Hayes tank also works well. No matter what tank you use, it is best to wrap strapping tape around the tank to keep it from rupturing. There is of no bigger a mess than having the pressurized fuel system leak inside the fuselage and radio compartment (another good reason to enclose your receiver in a plastic bag and tape it closed).

To prevent the "YS nitro bath," remember to release the pressure in the tank *first* before opening the fuel supply line to the tank.

The following picture shows the installation of the fuel lines in the airplane. This installation follows the diagram supplied with the engine instruction sheet. There are a few additions to this system that are not shown on the instruction

diagram. There are two "T" connections in each side of the system, which are used to fuel the airplane. The lines branching from the T's run through "Fuel Dots," little devices that have a plug in the end of the fuel line that can be pressed into a retainer installed in the fuselage. The plug can be pulled from the retainer, and then removed from the fuel line to vent and inject fuel into the tank. We warn you to unplug the vent line first to relieve the pressure before unplugging the fill line. If the fill line is unplugged first, you will receive the "YS nitro bath." We also install a fuel filter between the engine and the "fill tee" connection. This allows you to filter fuel before it enters the engine. The YS 120 is very susceptible to particulate matter in the fuel, which lodges in the regulator and causes you infinite grief. Install the check valve in the vent line.



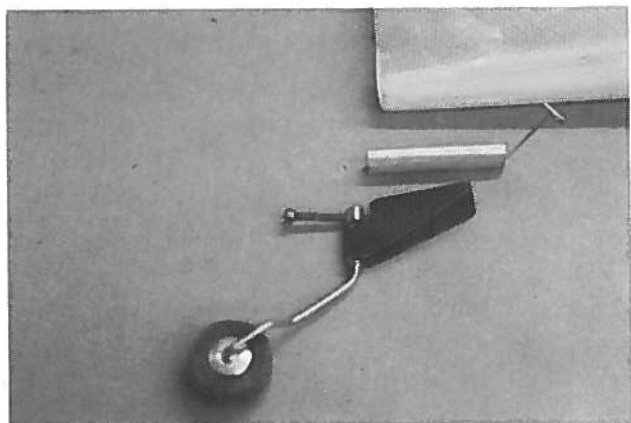
Fuel Line Routing With Fuel Dots And Tees Installed

## TAIL WHEEL

With a conventional landing gear configuration, the tail wheel is the steering mechanism for the airplane while it is on the ground. The tail wheel is mounted to the fuselage and connected to the rudder, which controls the airplane on the ground.

There are many variations to tail wheel installations. The configuration we use allows the tail wheel bracket to be replaced if it should be broken during a hard landing or become worn from many flights. The installation is very simple.

**8.32.** We use a Dubro 60-size tail wheel bracket and the accompanying hardware, a small wheel collar, and a 1" 4-40 bolt to secure the wire into the tail wheel bracket. File a small flat spot on the wire where the bolt tightens against the wire holding the tail wheel. Use a piece of hardwood dowel epoxied to the inside of the fuselage as back-up for the tail wheel bracket support screws. If you just screw the bracket into the fiberglass, it will only take a few flights before it either falls off or the fiberglass breaks.



Tail Wheel Components

**8.33.** During the final installation, slide a piece of fuel tubing over the 1" 4-40 bolt and punch a screw through it into the rudder for a connection point. The fuel tubing acts as a shock absorber. It does not allow sharp landing jolts to be transmitted into the rudder and rudder servo. If the tail wheel was connected directly to the rudder, it is possible that a landing jolt would strip the gears in the rudder servo.

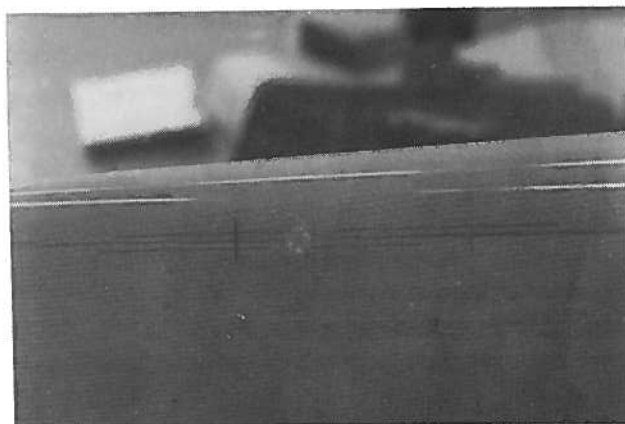


Final Tail Wheel Installation

## RUDDER CABLE EXITS FROM THE FUSELAGE

Ever wonder how some builders create such smooth holes for their rudder cable? In our earlier days we'd poke a hole in the side of the fuselage and call it quits. Well, one day we found out how to create a smooth exit. The following describes how it is done:

**8.34.** Begin by drilling a hole the diameter of a piece of Sullivan Golden Rod Sheathing, after locating the cable exit.



Initial Hole For Cable Exit

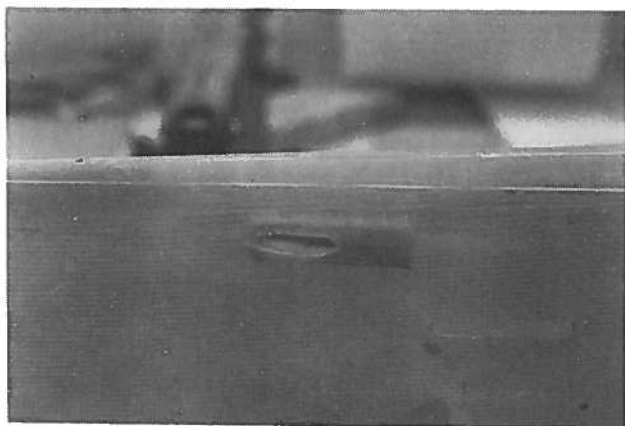
**8.35.** Make the hole into an oval the diameter of a piece of Sullivan sheathing.



Oval Hole For Golden Rod Sheathing

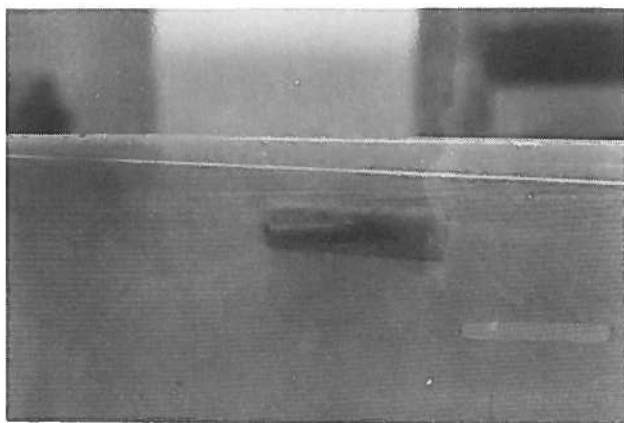
**8.36.** Cut a piece of balsa approximately 1-1/2" long and 5/16" square and glue it to the inside of the fuselage. Drill a hole the diameter of the Sullivan sheathing at an angle that will line up

with the rudder servo and the rudder control horn.



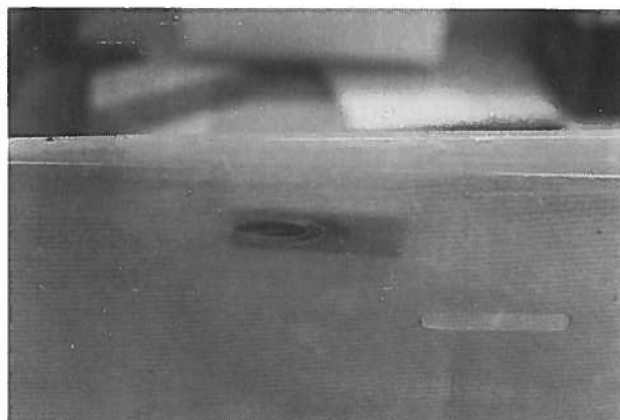
Balsa Back-Up For Sheathing

**8.37.** Slide a piece of Sullivan sheathing into the hole and glue it with CA.



Sheathing Installed

**8.38.** Cut the Sullivan sheathing almost flush with the outside of the fuselage. Then sand the Sullivan sheathing flush with the fuselage side. To fill the gaps and holes around the sheathing, use the automotive body putty you used for the fuselage seam. Once cured, sand down evenly with the sides of the fuselage. The result ... a very nice rudder cable exit.

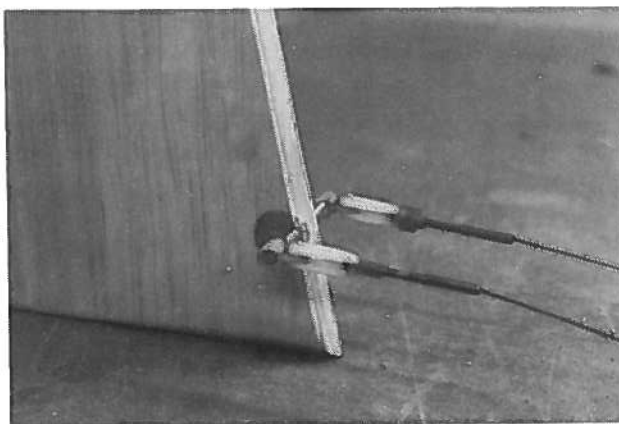


Sheathing Cut And Sanded Flush With Fuselage

## RUDDER LINKAGE

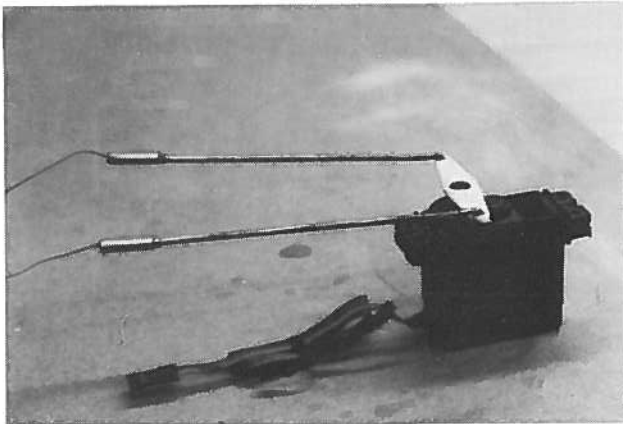
We haven't been impressed with what has been marketed for pull-pull rudder linkage. So, necessity being the mother of invention, we pieced our own linkage system together. All the materials can be obtained off the racks of your favorite hobby store. Let's start at the rudder and work to the servo.

**8.39.** Start with an all-thread rod about 1-1/4" long. Drill a hole through the hardwood dowel in the rudder and thread the all-thread rod through the hole. Screw a control horn on each end of the all-thread rod. Clip a clevis in the control horn and then screw a threaded coupling into the clevis. Solder a piece of control line lead-out wire into the threaded coupling.



Control Linkage At Rudder

**8.40.** Slide a piece of brass tubing over the end of the lead-out wire and then slide the brass tube and wire over the end of a piece of 4-40 rod. Solder the brass tube, lead-out wire and 4-40 wire together. With all the pieces assembled, mark where the 4-40 wire should be bent for the servo control arm. Bend the wire, cut off the excess, assemble the linkage and you're finished. *If anything wears out or breaks, there are always replacement pieces at the local hobby store.*



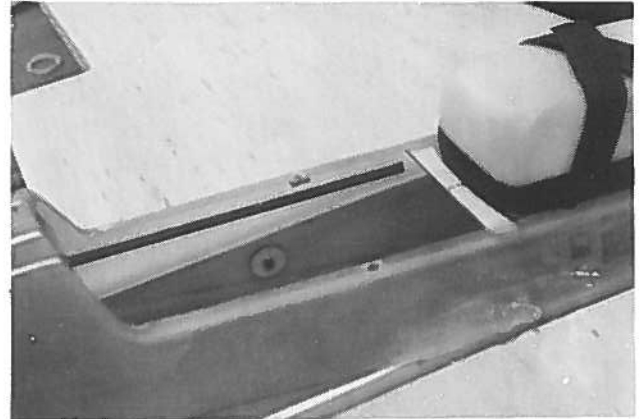
Control Linkage At Rudder Servo

## CONCEALED ANTENNA INSTALLATION

An exposed antenna can be one of the most annoying objects on an airplane. Inevitably, you'll catch it on something or it gets coated with fuel, stepped on, chopped off (which will more than likely put your airplane into the ground) or baked in the sun. In addition to what happens to the antenna, the exit out of the fuselage never looks nice and clean and the loose end just dangles out in space. A good way to solve this problem is to place the antenna inside the fuselage. We have found that the easiest way to do this is to install a hollow tube from the radio compartment area to the rudder post in the fuselage. We use Sullivan Golden Rod Sheathing.

**8.41.** While the airplane is still being framed up, and prior to installing the rudder post in the fuselage, place a piece of red golden rod sheathing inside the fuselage. Begin the installation at the radio compartment.

**8.42.** Place the sheathing against the side of the fuselage and tack glue it to the side of the fuselage with some CA.



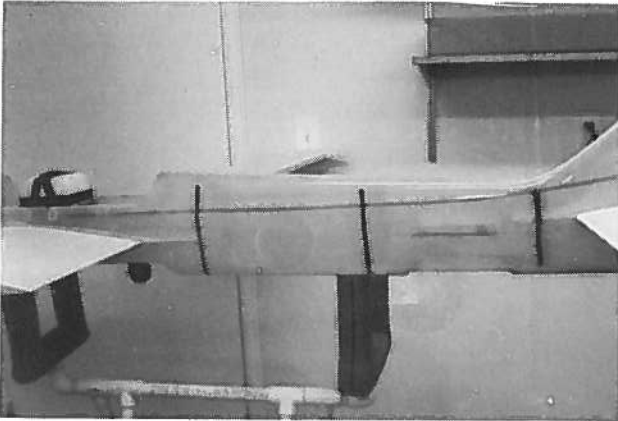
Sheathing Tack-Glued To Radio Compartment

**8.43.** With the fuselage placed vertically and the rudder post on the floor, press the sheathing against the fuselage and drop some spots of CA between the fuselage and sheathing.

**8.44.** Work your way to the back of the fuselage spot gluing the sheathing to the side of the fuselage with CA. When you get to the rear of the fuselage, turn the fuselage vertically, with the nose down.

**8.45.** Bend the sheathing up to the top corner of the rudder post area and spot glue it with CA.

**8.46.** Once you're satisfied with the routing and the amount of tack gluing you've done, use RC-56 adhesive and try to glue as much of the sheathing to the fuselage as you can. This is a very difficult procedure. You have to use the old "bombs away" technique with the glue to get it in the right spot. Do not use the CA to hold the sheathing to the fuselage; eventually the fuselage will flex and the bond will break, which leads to the tube vibrating against the fuselage. Then you'll be stuck with having to remove it, gaining nothing. Therefore, once again, use the RC-56 adhesive to secure the tube to the fuselage.



Sheathing Glued To The Inside Of Fuselage

When the time comes to install the antenna, just stick the end of the antenna into the end of the tube and push it along. How about *that*? A concealed antenna!

**CONGRATULATIONS! YOUR AIRPLANE IS  
NOW COMPLETE**

## Chapter 9 FLYING

### SURFACE THROW AND CENTER OF GRAVITY

The amount of control surface deflection is purely personal preference. However, because this book is intended for the first-time builder/flyer of a pattern airplane, we've taken the liberty to state what are moderate control surface throws. First-time flyers will find the low rates comfortable for general flying. (High rates are set aside for spins and snap rolls that might be controlled by a switch or button, but not general flying.) These throws should be used as a beginning point only. After flying an airplane, personal preference will dictate whether to increase or decrease the throws.

Surface	Rate	Left/Up	Right/Down
Rudder:	Low	1-3/4"	1 3/4"
	High	2"	2"
Elevator:	Low	3/16"	3/16"
	High	3/8"	3/8"
Aileron:	Low	3/16"	3/16"
	High	3/8"	3/8"

#### 9.1. Center of gravity:

Check the center of gravity balance point. The airplane should balance at the point noted on the plans. After trimming your airplane, you can move the center of gravity and adjust the control throws to suit your flying style.

#### 9.2. Lateral balance:

Be sure to statically check the lateral balance, the balance of the airplane along the longitudinal axis of the airplane. Suspend the airplane by its prop and tail wheel. Watch the airplane; if one wing is heavy add clay to the other wing tip. Once your airplane is flying you will dynamically check the balance of the wing weights. Once the airplane is balanced you can add the weight permanently inside the wing tip.

### TRIMMING

Trimming a model airplane is a combination of science and art.

"I vividly remember the first time I tried to 'trim' an airplane, other than to make sure it was flying straight and level. The process just dumbfounded me. I felt intimidated and thought it must be easier to fly a misaligned airplane than to try to perform this trim process.

Fortunately, Don taught me the process and convinced me that trimming was well worth the time and effort. I will admit it was difficult to grasp the concepts at the beginning. However, I find that the more I fly and work on trimming my airplane, the easier it becomes. I now know the joy of flying a trimmed airplane and learning and performing the trimming process was definitely worth the time and effort." --Bruce--

*Trimming is the act of adjusting the airplane control surfaces so the airplane will fly straight and true, performing the maneuver you wish by using just the "text book" control inputs.* For example, a "text book" input for a loop is to enter the maneuver straight and level, gently pull the elevator until you reach the desired radius, hold that position with no other inputs until the airplane levels off at the bottom, and then gently release the elevator input. Even with a perfectly trimmed airplane this single input would not result in a perfect loop. However, with a trimmed airplane the amount of additional input required to perform a perfect loop is dramatically decreased. Contrarily, a poorly trimmed airplane will require as much additional input to perform the maneuver as the required primary input. Therefore to enjoy and improve your flying, trimming your new pattern airplane is a must. Unfortunately, like everything else in the hobby, trimming, to the beginner, appears to be an incredibly complex procedure. But trimming is like everything else. The more you work at it the more proficient you become.

Also understand that trimming is a compromise. You might find that trimming the airplane to perform one maneuver might adversely affect the way it performs another maneuver. This will become more evident when you become more proficient at flying and better at trimming your airplane.

*The important point to remember is to take trimming one step at a time. If it gets too complex, or you get frustrated, just back off.*

Adjust only one item at a time. Trimming is one of the most rewarding and tedious tasks associated with flying a pattern airplane. A well-trimmed airplane is a joy to fly. Conversely, a poorly trimmed airplane is a handful to fly and not much fun at all. The trimming process we have outlined goes through the following steps:

- Setting control surface deflections
- Straight and level flight
- Engine thrust
- Center of gravity
- Looping

Each one of these steps will be explained in detail and should be followed in this order. Each of the steps builds on the preceding step. If you try to adjust for inside loops before trimming for straight and level flight and engine thrust, you've eliminated a systematic approach to trimming and will do a lot of adjusting without accomplishing anything.

Trimming an airplane starts with the building process. Without an airplane that is built straight, your chances of trimming success are low. Make sure the airplane is constructed straight and all the flying surfaces are aligned and sealed properly. Take the time to perform the construction alignment process properly; it will pay dividends when it's time to fly the plane. Once the airplane is constructed, it's very important that all the control surfaces deflect equally and evenly. Moving a control horn in or out one revolution on a 4-40 bolt will noticeably affect the trim of an airplane when you become proficient. To ensure that all of the surfaces

deflect equally and evenly, check by attaching a deflection gauge to the control surfaces. This is covered in detail in the "Deflection Gauge" paragraph in the "Additional Topics" section.

*After you have checked to make sure the airplane is straight, that the center of gravity is placed properly according to the plans, and the complementing control surfaces are deflecting evenly and equally, then you're ready to fly the airplane.*

When making trim adjustments to your airplane, keep in mind what you're doing to its aerodynamics. Analyze what adjustments you need to make. After noticing some peculiar characteristic of the airplane during a maneuver, land it, sit down and analyze the movement in your mind. Determine what's causing the problem and what adjustment it will take to correct the problem. Sometimes you'll sit and go through this thought process for a long time. *When you've determined what the problem is and what adjustment needs to be made, make only one adjustment at a time.* Whether you're just beginning, or if you're an experienced flyer, this point can't be over-emphasized. For instance, don't make adjustments to the elevator and ailerons at the same time. You need to keep track of each change you want to make, the adjustment you make and the outcome of that adjustment. If you make multiple changes at one time, you'll lose track of what's happening, become frustrated and give up. To you're your frustration and high blood pressure, take the trimming process one step at a time. It will typically take many flights to trim the plane. Don't try to short circuit the process. It will just create bigger problems for you.

### 9.3. Setting control surface deflections:

Become accustomed to the airplane during the first few flights. Perform many passes, upright and inverted, up wind and down wind, to rough-trim the airplane for straight and level flight. Once you're satisfied with the straight and level flight trim of the airplane, perform some very rudimentary maneuvers consisting of Immelmanns, loops, stall turns and rolls. Don't

perform any more complex maneuvers immediately. Learn the specific characteristics of the airplane. In addition, watch how it performs the various maneuvers and what adjustments will be needed after the flight. After landing, and while the necessary corrections are fresh in your mind, adjust the control surface throws. Maybe the ailerons are not responsive enough, but the elevators are *too* responsive; adjust them to your liking. The next few flights are used to determine what minor adjustments might be necessary to make the airplane fly correctly. After you have a good idea of what the flying characteristics of the airplane are, and you feel comfortable flying it, then it's time to begin the trimming process.

#### 9.4. Straight and level flight:

The first step in trimming is adjusting the plane so it will fly straight and level and to determine if wing weight is necessary. Fly the airplane in front of you, making passes in the upright position. Adjust the trim levers so the airplane will fly in a straight line without rising or lowering or turning right or left without having to input corrections.

Next make some inverted passes. If the plane needs any correction in the heading, wing weight is necessary. If the airplane flies straight and level upright, but turns to the right inverted, the left wing panel is "heavier" than the other. This could be due to construction weight or to differences in wing panel incidence. Either way, land the airplane and place a piece of modeling clay on the right wing tip. Take off, and adjust the airplane to fly straight and level in the upright position; with the additional weight on the left wing panel, the trim in the upright position will change. Once trimmed in straight and level flight in the upright position, invert the airplane and make passes in front of you. If it flies straight and just needs a little down elevator, you've applied the proper amount of weight to the wing tip. If the airplane still turns to the right in the inverted position, but not so dramatically, add more weight to the right wing tip. If it turns to the left in the inverted position, remove some of the weight. This process takes some time but you

must do it to continue. Once the airplane will fly both inverted and upright in a straight line with the application of some down elevator in the inverted position, you're ready to continue to the next step.

#### 9.5. Engine thrust:

Now it's time to check the side thrust of the engine. Most airplane kit fuselages are manufactured with some right thrust for the engine. With the new long stroke engines and high pitch props, most airplanes we have flown require more right thrust, in addition to what the manufacturer has built into the fuselage. To determine if the engine thrust is correct, perform the following maneuver: Fly the airplane upright, heading into the wind. Gently pull the airplane from the horizontal position to the vertical position. As the airplane rises, watch its direction. If it yaws (flat turns) to the left it needs right thrust. Conversely, if it yaws to the right it needs less right thrust. To make this adjustment, place one washer behind the left engine mount for more right thrust, or one washer behind the right engine mount for less right thrust.

#### 9.6. Center of gravity:

Begin by flying the airplane into the wind at full throttle. When the airplane is approaching you, throttle the engine to idle. Watch it carefully. If the airplane continues flying forward, appears to glide properly and slowly loses altitude, the balance of the airplane is correct. If, after throttling the engine to idle, it immediately starts to lose altitude, the center of gravity is too far forward. Re-adjust the weight inside the airplane and move the center of gravity back. If the elevators are extremely responsive with very little throw and the airplane loses very little elevation after reducing the throttle to idle, then the center of gravity could possibly be too far back. Watch this condition; it's easy to crash an airplane if the center of gravity is too far back. *It is better to have the center of gravity a little farther forward and adjust it back than to start flying the airplane with the center of gravity too far back.*

### 9.7. Looping:

There is nothing more aggravating during a loop than having the airplane corkscrew in or out when you're flying into the wind and are inputting just elevator. This problem results because the rudder is not trimmed properly, or the elevator halves are not aligned perfectly.

To begin the rudder and elevator halves trim process, start by performing inside loops. To position the airplane properly for inside loops, fly the airplane towards you and into the wind at the same time, if possible. As it approaches, gently apply up elevator and watch the airplane. If it moves to the left, move the rudder trim to the left. Adjust the rudder trim until the airplane tracks in the loop without wavering either right or left. When the airplane is trimmed to do inside loops, it's time to check outside loops.

We can determine if the elevator halves are perfectly aligned by performing outside loops after the airplane is trimmed for inside loops. When you get to this point in the trimming process, the trim of the rudder and the elevator halves are integrally related. Place the airplane in the same position as it was for the inside loops, heading into the wind and towards to you. When the airplane is close and inverted, gently push in down elevator and watch the airplane. If it doesn't move right or left, congratulations! The airplane is basically trimmed. If the airplane is moving right or left, then the elevator halves are *not* properly aligned. If the airplane is inverted, flying towards you and moves to your left, the left elevator is too low. To remedy this, raise the elevator by rotating the elevator clevis out one or two turns. Now, if you've adjusted an elevator clevis, it is important to re-trim the rudder by performing the inside loop trim sequence again.

Now it's time to grasp an important concept. *If the airplane is apparently flying straight and true in inside loops and the elevator halves are out of trim then the only way the airplane is in a "trimmed" condition is to have an equal and opposite force applied by the rudder.* If you begin to trim the elevator halves so they don't

have the rotational influence on the airplane and the rudder remains in the same position, then the rudder will impart an unbalanced force that will cause the airplane to turn. Therefore, once you adjust the elevator halves, trim the rudder by performing the inside loop trim process. Then, once the airplane is trimmed in the inside loop, perform the outside loop trim process again. If the airplane still moves right or left while performing the outside loop, keep adjusting the elevator halves and begin the looping trim process again. Once the airplane is not moving right or left during an outside loop and all the other trim processes are set straight and true, your airplane is trimmed for basic maneuvers.

*Trimming the elevator halves and the rudder is a time-consuming process. Take the time to do it right and the enjoyment of flying your new pattern airplane will increase dramatically.*

You have just finished trimming your airplane; the process is complete! Yet, this is not necessarily true! We've found that trimming is a never-ending process. *It seems that an airplane is constantly changing and requires regular trimming input.* We might notice that one wing tip is dropping in a maneuver, and, after the trimming analysis previously presented is performed, we're twisting a clevis a turn here-and-there to correct the problem. Also, we've found that as you become a better flyer, the trim on the airplane becomes more critical. Your sensitivity to minor problems becomes more pronounced, requiring small trimming corrections. *It might seem trimming is arduous, but actually it becomes fun and quick.* Just like anything else, the more you perform trimming functions on your airplane, the easier and quicker it becomes.

Now that the building and trimming processes are complete, it's time to go flying. If you're a person who's willing to take on building a pattern airplane, you already have a turn-of-mind that sets goals and practice-time. However, it's been our experience, working with inexperienced flyers, that if we outline how and why we practice

the way we do, others may glean a nugget of knowledge that will help them with their "learning curve." Therefore, the following sections on goals and practicing are included to help you develop your own goal-setting and practicing techniques.

## GOALS

Every aspiring pattern flyer should set goals. Setting goals and achieving them successfully is what drives your motivation and enjoyment of the hobby. There are two goals: long and short term. Short term goals are for a day, or week, of flying. Long term goals are for a season, or years to come. *Your goals must be achievable!* Take the time to set realistic ones. If you're a novice flyer and your goal is to become world champion in two years, it's probably unrealistic. However, if you're a novice and want to move up to the sportsman class within a year, this is probably an achievable goal.

While you have some idle time, or during your commute to and from your job, think about what your long and short term goals are going to be for this season and into the future. To set your goals you must evaluate your time commitment. Do you want to move up a class or do you want to stay where you are? How much time do you have to devote to practice during the week? Is your equipment well maintained or do you have to spend potential flying time on maintenance or building a new aircraft? How many contests can you attend? Are most of your weekends spoken for, or are you free to travel every weekend to a contest? Once you've evaluated your time commitments, you can establish your goals and schedule. With these thoughts fresh in your mind, grab a calendar, the district schedule and determine the contests you wish to attend.

Maintaining your level of skill is not a bad decision. At the end of the 1992 pattern season, Bruce and his wife decided to build a new house.

"I knew this would take a major portion of our time during the winter and spring of '92 and '93. I was deeply involved in the project and realized that there was no way I was going to improve my flying during the '93 season because of the house construction commitments. However, this did not keep me from flying in a number of contests with only a little practice. It just meant I had to set my goals realistically to fit in with my time constraints. *I still enjoyed the season because I set my goals to 'maintain.'*" Remember, this is a lifetime hobby. You needn't jump from winning a novice contest to competing in the FAI class in one season. The important point to realize, is *not* to set your goals higher than you can attain and enjoy yourself.

## GUIDELINES FOR PRACTICE

You need a straight and trimmed airplane and practice to be a successful pattern flyer. How you approach practice can have a profound impact on your improvement or lack of improvement. Practice can be constructive or destructive to your improvement. In addition, how you progress depends upon how you apply yourself while you practice. It is a given that if you practice long enough you'll improve. But if you apply some of the following principles your rate of improvement will increase.

Your practicing should be very disciplined ... fun, but disciplined. Every aspect should be structured so you obtain optimum benefit from the time allotted. This is not to say that once you step into your car at home to the time you return to the dinner table, you will be focused on nothing but pattern flying. There is always time for the usual round of chatter and camaraderie at the field. But, when you fly, it's time to become very focused on your objectives. Let's cover what many top flyers consider to be important points to practice.

**9.8. You "gotta wanna do it!"** It takes a lot of self motivation to fly and be competitive in pattern competition. Some people have an incredible drive early in their pattern career to be

the best and improve. However, as the years move on and the newness wears off, so does the motivation. To be good at anything, whether it be pattern competition, chess or race car driving takes dedication, motivation, competitiveness and a desire to improve. Without these characteristics you won't last. You just have to want to do it or you won't progress. If you find yourself not wanting to practice because of outside problems, time commitments, or lack of desire, walk away from pattern flying for a while. Go do something else. If you do fly under an umbrella without proper motivation, you do yourself a disservice and your practice effort will be worthless.

As you practice more frequently, there is a fine line between being under-and over-practiced. If you cross the line to over-practice, you become stale and lose your desire to improve. If you do not practice enough, you remain at the same level or possibly lose your abilities. So the point is, watch the line. If you cross the line and lose your desire, then take a break.

"Early in my learning stages of pattern flying, I fell in the trap of practicing too much. I work very close to a local flying field. During the flying season, after work, I would depart for the flying field whether I was up to it or not. I felt like I must practice to improve. I would put in three or four flights each night. This worked very well early in the season. However, as the season continued, I wore out. I noticed that my flying was not improving. I thought I needed more practice. I practiced more but I did not improve. I thought I needed more practice ... and on and on. This was a vicious circle. When I realized that I had over practiced, the season was over. My results were poor and my attitude was terrible. It took most of the winter to recover mentally and I reached the point that I wanted to fly again," says Bruce.

It is important to fly frequently. But it is also important to get away from flying and give your mind a rest. Everyone is different, just monitor your attitude. If you jump out of the car, can't wait to fly and you still have that attitude after

your third flight, you're probably in good shape. However, if you jump out of the car, talk to everyone, make a flight and you feel "stale" then just pack it up and put the show on the road home for the day. *How you utilize your practice time is more valuable than how much you fly. Or in other words, strive for quality not quantity.*

**9.9. Plan your flights for the day.** As you are driving to the field, think about what you want to accomplish. A strategy might be to fly the entire pattern for the first flight, work on the first three groups of maneuvers for the second flight and the last group of maneuvers and the whole pattern for the third flight.

**9.10. Plan each flight.** Before you start the engine you should know exactly what you are going to practice during your next flight. Don't just start the engine, take off and fly some maneuvers. This gets you nowhere. Define what you want to improve. Identify your weaknesses and work on them. If you avoid your problem maneuvers you will not improve.

**9.11. Set goals for each flight.** If you plan on working a segment or particular maneuver then set a goal. For example, do three Cuban eights on top of each other consecutively. Do this until you accomplish your goal. Don't get frustrated if you can not accomplish your goal. If you can't accomplish the goal move on, but at least give it the good old college try. After you accomplish one of your flight goals, then move on to the next maneuver or group of maneuvers that needs improvement. This helps you polish the maneuvers and correct the little errors.

**9.12. Analyze each flight after completion.** After each flight analyze what maneuvers you do well and which maneuvers need some work. Then, when you are ready for the next flight, work on the maneuvers or sequence of maneuvers you feel need work. Do this as you are walking back to the pits or putting away your transmitter. But do it before you start talking to everyone in the pits.

**9.13. The "three" rule.** The three rule is, "practice three times a week and make three flights each practice session." This is of course a guideline only and not to be construed as gospel. However, it does have incredible merit. If you give your mind a rest between practice sessions then it can think about what to improve and get recharged for the next session. If you fly too much it turns into a second job and you lose the fun. This goes back to the adage that you "gotta wanna do it!"

What you are trying to do is establish good flying habits. If your concentration is off or you're not really feeling up to practicing, then all you're doing is reinforcing bad habits. Therefore, if you're flying like a world class champion, put in an extra flight or two to help the positive reinforcing habit. However, if you're flying like you have no connection to the airplane, even during the first flight, pack the show up and put it on the road. Don't take a chance on moving backwards at any time. "I must admit, packing up my stuff after the first flight is one of the hardest things I have had to do. But in the long run it has paid dividends. I have found that the next time out I'm raring to go and I am very productive," says Bruce.

**9.14. Concentrate on the basics.** Concentrate on every aspect of each maneuver. As you practice groups or segments of maneuvers concentrate on size, composition, geometry, radius of corners, symmetry about the centerline, vertical and horizontal lines. *Become aware of exactly what the airplane is doing.* If someone tells you that you are pulling your nose up during a four point roll at the beginning of the maneuver, very critically watch the next time you do a four point roll and try to see the problem. *The more you become aware of exactly what the airplane is doing on your own, the easier it is to improve.* This is because you are identifying your own mistakes and correcting them before you are told. Watching the basics is where to start.

**9.15. Put the pressure on yourself.** When you are practicing, put the pressure on yourself to fly like you are in the world championships. Concentrate and follow through with each group of maneuvers. Fly like you were in real competition and the judges are standing right behind you. You will be surprised at how this improves your flying and your nerves at the next contest.

**9.16. Make the first flight count.** Contests generally have at least one or two rounds that can be thrown away. However, even with throwing a round out, contests can become very close at the finish. If you think of the first flight of a contest as the "throw away" round and use it as a warm-up you are handicapping yourself. The person that can make every round count and flies with consistency is generally the one who places very high. During practice, we generally plan on using the first flight to fly my pattern from take-off to the last maneuver (we don't do the landing if the field is crowded). We fly the first flight as though we are in a contest and it is our first flight. We concentrate and watch everything during the flight. We do this to train ourselves for the first flight of a contest.

**9.17. Break the entire pattern into groups of maneuvers.** It is important to practice groups of maneuvers. You might find that the problem with your maneuver is not in the "body" of the maneuver but in the entrance to the maneuver. You might be entering a maneuver with your wings not level, the nose might be high, too long an exit from one maneuver offsets the centering of the next, not utilizing all the box with the turn around maneuvers, etc. Break your pattern down into small groups of manageable maneuvers that can be practiced over and over. For instance, in one of the more advanced patterns, you could have a maneuver grouping consisting of: square loop with 1/2 rolls, 1/2 reverse Cuban eight, four point roll, Immelmann, reverse top hat, 1-1/2 turn spin and then back to the square loop with 1/2 rolls. This can be practiced numerous times during a flight and the continuity of the maneuvers can be maintained.

Look at the particular pattern you fly and make manageable groupings that you can fly and improve.

**9.18. Don't give up on a group of maneuvers.**

You just came out of a 1/2 reverse Cuban eight and are heading for a slow roll when you realize that your heading is not-so-perfect. Instead of quitting and starting the 1/2 reverse Cuban eight over, just try to put the airplane back on heading. This is not a perfect world and there are no perfect flights. If you work on corrections more and more, then there will come a time that you will apply fewer and fewer. But the only way that happens is not give up on the group of maneuvers. Follow through with your plan and finish the group even if it is the worst group of maneuvers that you have ever performed.

**9.19. Watch other flyers.** Not to get Zen on you, but at practice and contests watch other, better flyers. Don't just watch them while conversing with your buddy but *watch* them. Look at the size of their maneuvers, the pace of the flight, basics like vertical and horizontal lines, composition of the maneuvers: Are they flying close with compact maneuvers or are they far out and flying big maneuvers? Go so far as to silently announce each segment of a maneuver and try to fly with the pilot, anticipating each movement of each maneuver. Your dialogue for a square loop with half rolls might be: pull vertical ... roll ... push horizontal ... roll ... pull vertical ... roll ... push horizontal ... roll. The idea is to develop a pattern for your mind that you can use as a reference when you fly. By doing this, you develop a keener eye for details. This keen eye will definitely help your flying. The trendy word for this is "visualize." Sports psychologists are using it more and more. So, to become fashionable and trendy, you might as well jump on the band wagon. "At the risk of sounding sarcastic, I must admit it has helped me progress and we highly recommend it to anyone," says Bruce.

**9.20. Use your friends.** Seek out other pattern flyers to fly with. If you're flying with a friend,

have him or her watch for mistakes. Listen to what they say and set your ego to the side. Hear their critique and utilize their comments to improve where they believe you have problems.

**9.21. Don't be critical of yourself.** Some days you have it and some you don't. On the days you don't have it, don't be hard on yourself. Accept the fact that you can fly, but this is an off day. Don't torment yourself by first starting to say to yourself, "I can't fly a round loop!" Next you say, "I can't do any maneuver well!" Then it's, "I shouldn't be flying an airplane, I should just quit!" This is counter-productive and you should just stop. Just say, "The next day out will be better," and move on.

"One day, years ago, when I played tennis very avidly, I was hitting the ball everywhere except in the other court. I was becoming very frustrated and ready to give up playing tennis for ever, not just for the day. My coach, after watching me for a period of time, walked up and very candidly said, 'Don't let your expectations exceed your abilities.' After that very frank statement, I evaluated my present ability. I realized that in my mind I wanted to play like a professional tennis player, but my ability was much lower. When I realized where my real ability level was, my frustration level decreased. I settled down and enjoyed my remaining game of tennis. Unfortunately, my ability to hit the ball did not improve, but my attitude sure did. Instead of being too critical of myself, I just realized that it was an off day and I should just accept it. Believe me, I have a lot of off days with my flying as well," says Bruce.

**9.22. Recognizing where you need improvement.** The way you do this is with the results from all your previous contests. Everyone has results from contests except the first time contestant. Now, take those results and organize them in a fashion that you can use to evaluate your flying. Do not think that the judging was too hard at the last contest and it does not reflect how you really fly and that you should not use those results. Keep in mind that you flew six

rounds in front of two judges which gives you twelve sets of scores to work from. The chances of all the judges not being fair with their perception of your flying capabilities are very low. Be honest with yourself and accept this information constructively.

With modern computers it is easy to organize these results in a manner that allows you to review them quickly and decide which maneuvers you need to work on to improve. We have included an example of a spreadsheet showing the results from one of our earlier contests when Bruce flew expert turnaround.

ARVADA PATTERN CONTEST															
JUNE 9, 1991															
EXPERT TURNAROUND															
RAW SCORES	K-FAC	RD-6	RD-5	RD-4	RD-3	RD-2	RD-1								
1 TAKEOFF SEQUENCE	1	8	8	8.5	7	0	0	0	0	8.5	8	7	7	5.2	
2 AVALANCHE	3	8	7	8	6	7	7	7	8	7	7	6.5	6	7.0	
3 HALF REVERSE CUBAN EIGHT	1	9	7	8.5	8	8	8	8	8.5	8	8	8	7	8.0	
4 SLOW ROLL	3	9	7	7	7	9	8	8	7.5	8	7	6.5	8	7.7	
5 HURRY! BLUP 1/2 OPTIONS	1	8	7	7	8	8	7	8	9	7	7.5	7.5	7	7.6	
6 SIX-SIDED INSIDE LOOP	4	7	7	7.5	6.5	6	6	7	7	6	6.5	6.5	7	6.7	
7 IMMELMANN TURN	1	8	6	7	8	6	7	8.5	9	7	7.5	8	8	7.5	
8 OUTSIDE SQUARE LOOP	3	7	7	7	6.5	8	8	8.5	8.5	6.5	6	7	6	7.2	
9 1/2 ROLL INTO 1/2 SO LOOP	1	8	6	7	8.5	7	8	8.5	8	7	7	7.5	7	7.5	
10 TOP HAT	3	7	6	6	7	7	7	7.5	7.5	7.5	7	7	7	7.0	
11 STALL TURN	1	8	7	8	8.5	5	4	6.5	7	7	7.5	7.5	8	7.0	
12 FOUR-POINT ROLL	4	8	7	6	6.5	6	5	7	7.5	6	6	7.5	6	6.5	
13 STALL TURN 1/2 ROLL	2	7	6	7	7	6	4	7	7	6.5	5	6	5	6.1	
14 DOUBLE IMMELMANN	2	8	7	6.5	7	6	6	7	7.5	7	7	7	7	6.9	
15 TOP HAT WITH 1/4 ROLLS	2	7	6	6.5	6.5	7	7	7	8	7	8.5	8	7	7.1	
16 KNIFE EDGE FLIGHT	3	8	7	8.5	6.5	8	7	6	6.5	6	6	6.5	5	6.6	
17 LANDING SEQUENCE	1	8	8	7	7	5	5	4	7	8	7.5	8.5	8	6.9	
36															
AVERAGE RAW SCORE															7.0

With this simple spreadsheet he could determine his overall average score for the contest and evaluate where he needed to improve. To configure your own spreadsheets, use the format shown. Sum all your scores to the right and divide by the number of sets of scores you have recorded. Take the average scores on the right and sum them down and divide by the number of maneuvers in your sequence. With the values from this spreadsheet, you can quickly compare the average raw score against other contest results to see if you have improved or regressed. Take this evaluation with a grain of salt though. Each contest is different regarding the conditions under which you flew.

"I remember the particular contest I received these scores. The late afternoon conditions were terrible. The site was located on the top of a very exposed mesa, the wind was howling about thirty miles-per-hour directly across the runway and I was not too adept at taking off under such

conditions. Subsequently, I was all over the runway and crossed the edge causing me to score zeros on two takeoffs," says Bruce. The point is, use the average raw score to get just a feel for where you are in comparison to other contests.

After looking at the average raw score, look at each maneuver compared with the average raw score and determine which maneuvers are below your average. At the same time, look at the k-factor for each maneuver to determine if the low score maneuvers are also high k-factor maneuvers. The quickest way to improve your overall placing is to concentrate on the below-average-scored high k-factor maneuvers. Knowing what maneuvers are scored below average indicates what maneuvers need to be practiced. Once you have determined what maneuvers need work, it's time to go fly.

## Chapter 10 CARE AND MAINTENANCE

### AIRFRAME

Your airplane is now complete. It's flying and trimmed. You have committed a substantial investment of both time and money. Don't treat it like some sport flyers treat their airplanes. At the end of a day of flying, empty the fuel from the fuel tank, wipe some of the oil and dirt off, take it home, wait for next week to fly and then maybe remember to plug in the batteries for a quick charge. Rest assured, if you treat your pattern airplane, or for that matter, *any* expensive airplane that way, you won't have it for long. *Pattern airplanes require maintenance!* You're working with highly technical and sophisticated equipment. The engines and radios in today's pattern airplanes are quantum leaps above the standard equipment used by most flyers. It's important to take care of and maintain, not just the radios and engines, but the airframe as well.

To maintain and care for a pattern airplane correctly, you must develop a "check list" for every function you perform. For example, before each flight you should check the following:

**10.1.** The radio is on and all transmitter switches are in the appropriate positions.

**10.2.** All control surfaces are responding to the transmitter inputs.

**10.3.** All control surfaces are in the neutral position (or at least in a familiar position if certain trims are being input).

After each day of flying you should perform the following *minimum* checks:

**10.4.** Empty the fuel from the fuel tank.

**10.5.** Burn out the fuel that exists in the fuel lines and engine.

**10.6.** Squirt a little "after run" oil in the engine and turn the engine over with your hand to

circulate the oil. If you have a YS engine, don't inject any oil that might react with the silicone diaphragm. If in doubt, just run the engine out of fuel.

**10.7.** Make sure the carburetor venturi is closed.

**10.8.** Turn off the receiver and transmitter.

**10.9.** Wipe the entire airframe with a soft cloth to remove dirt and oil.

**10.10.** Check all clevises, hinges, control horns, retract mounting bolts, hatch covers, servo wheels, servo mountings, engine mountings, and propeller and spinner for wear and security.

**10.11.** Check the retract landing gear system for clearance, possible rubbing of the wheels against the wheel wells, and security of the wheel axles.

**10.12.** Wrap a clean cloth around the engine and front of the airplane to prevent dirt and dust from collecting around the carburetor intake.

During the flying season, perform routine maintenance on the entire airplane. This is a much more thorough inspection than the daily inspection. Replace any parts that show wear. At a minimum, you should check the following:

**10.13.** Remove the engine from the airplane, disassemble and inspect all pieces, replace any worn parts, reassemble and install them in the airplane.

**10.14.** Inspect each servo arm or wheel for wear and fit. If any excess play is noted, replace the worn part.

**10.15.** Thoroughly check all linkages, clevis and push rods for wear and fatigue by opening each clevis and inspecting the horn and the clevis for wear.

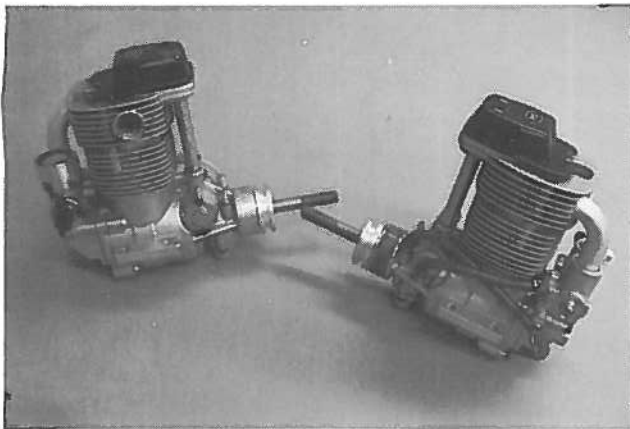
*Routine care and maintenance of your airplane can't be over-emphasized.* You will be able to spot potential problems that might lead to a disaster. It is also very gratifying to go flying and actually fly instead of fixing and adjusting parts that should have been adjusted or repaired in the home workshop.

## PROP SELECTION

We have been asked many times about what prop works best. Unfortunately, this is strictly a personal preference. However, we like quiet airplanes, so we like using props that give us high performance and as little sound as possible. The larger the prop, the slower the engine will spin. If the engine is spinning slower, the prop tip speed will be slower and the amount of sound generated will be less. However, if the prop is too large, the engine will labor and lack performance. Therefore, the choice of a prop is a compromise: low speed, low sound and low performance or high speed, high sound and better performance. After experimenting with a number of props, our favorite is the 15x11 manufactured by APC for the YS-140FZ. With this prop, the engine will spin at 8900 RPM (which is a nice low RPM for a YS) and with the combination of the 15x11 prop and the AAP pipe, our sound readings are around 94 db. This db level is very acceptable to the FAI judges and results in a nice speed for the aircraft. Our performance is not compromised, either. We have plenty of power to perform the long vertical lines required of the latest patterns. We are still experimenting with props for the YS-140L. This engine seems to need a bigger diameter and pitched prop because of the increased horsepower over the YS-140FZ. Our suggestion is to ask flyers in your region what works for them. Props are relatively inexpensive. It doesn't hurt to experiment. Just don't overload the engine with too big a prop. You might do irreparable damage to the engine.

## Chapter 11 THE YS ENGINE

The YS engine is a four-cycle engine designed primarily for contest pattern flying and scale competition models. It is equipped with a miniature supercharger and Variable Pressurization System (VPS) fuel injection system specifically designed for model airplane operations. The YS engine has gone through many changes since its inception. There have been six models manufactured: the YS-120SF, YS-120AC, YS-120NC, YS-120SC, YS-140FZ and now the new YS-140L. In addition, there have been changes to the models: the YS-120SF started out with small valves, then the engine was modified with enlarged valves and a larger main bearing/smaller crankshaft was incorporated. As the engine has evolved, its power output has steadily increased. Today the engine is the choice of the majority of pattern flyers.



New YS-140FZ And YS-140L Engines

### ENGINE BASICS

The principle behind our model airplane internal combustion engine is to create an environment that will allow an energy source to burn rapidly and under control, thereby creating tremendous volume change in gases and transforming that energy into the ability to spin a propeller. The key ingredients for an internal combustion engine are:

- A fuel source;
- Oxygen;

- Heat;
- Compression.

In our engines the fuel source is a mixture of nitro-methane, methanol and oil; the oxygen comes from the air ingested into the engine; heat is supplied by the glow plug; and the compression is supplied by the engine configuration. When mixed together we have the ingredients for a YS engine.

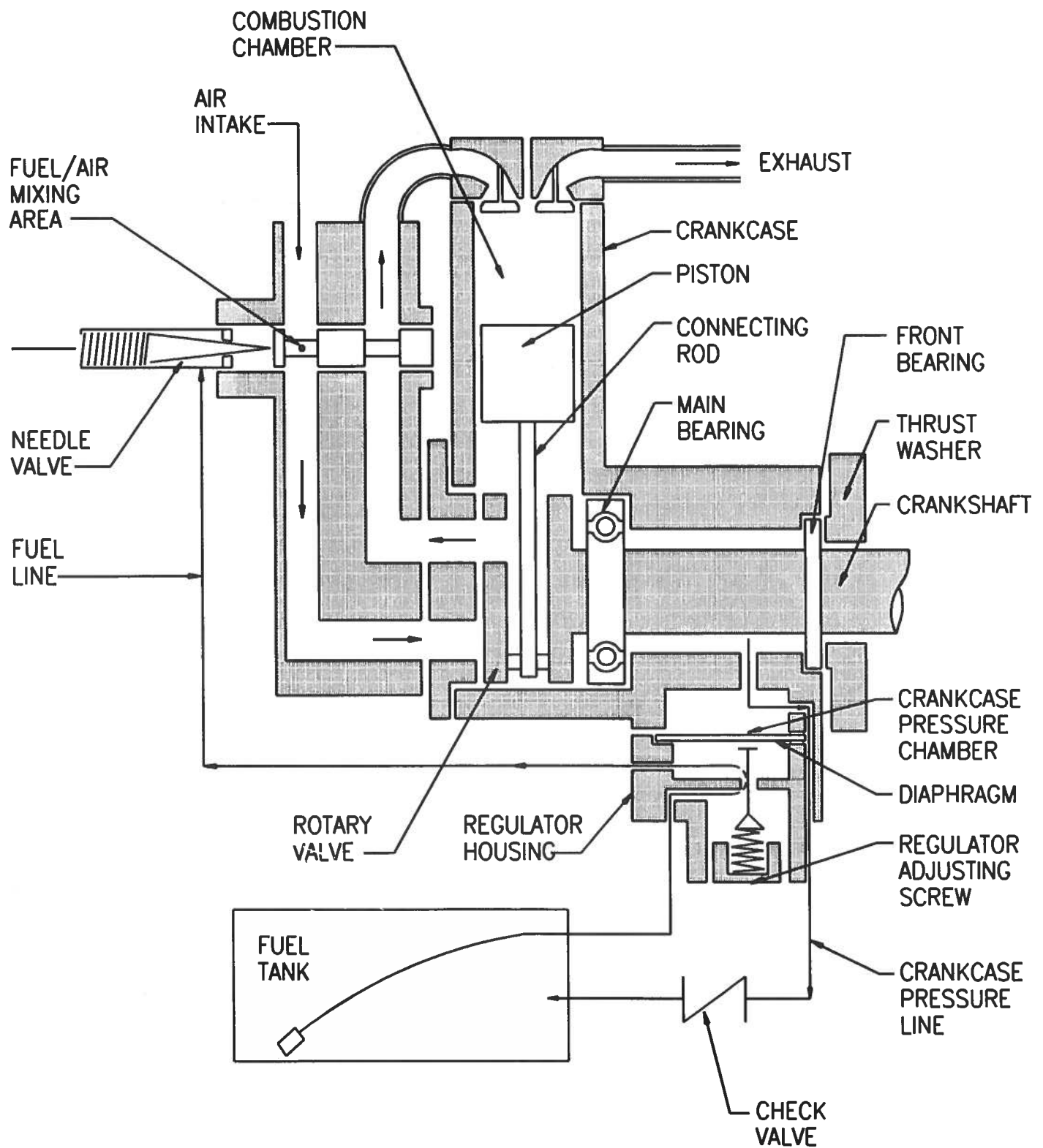
### COMPONENTS OF THE YS ENGINE

Before explaining how a YS engine works, a review of its components is noteworthy. Review the exploded view diagram of the engine that is included with your engine. Study where the components are located on/in the engine. The regulator, rotary valve, and air box (only on the YS-120AC) are unique components of the YS.

### HOW THE YS ENGINE OPERATES

The YS engines are supercharged, fuel-injected, internal combustion engines. It derives its power from the pressurization of the raw fuel/air mixture being injected into the combustion chamber. Although it appears to be complex, the engine and the components are relatively simple when broken down and explained.

Most model aviation engines utilize the same principles of power generation. They draw a fuel/air mixture into the combustion chamber, burn it and expel it. How the YS engine performs this process differentiates it from other model engines. Model aviation engines can be thought of as two distinct air pumps separated and sealed from each other by a piston and piston ring. The upper air pump is the combustion chamber; the lower air pump is the crankcase chamber. In addition to the basic two air pumps, the YS engine has approximately five other systems that work together to produce the power needed to propel our airplanes.



**SCHEMATIC DIAGRAM OF THE YS-120 SF**

The YS engines are four-cycle engines. The cycles are intake, compression, power and exhaust. Starting at the top of the intake cycle, the intake valve opens and the piston descends. A fresh fuel/air mixture is drawn into the combustion chamber. As the piston reaches the bottom of the stroke, the intake valve closes. The piston begins ascending and with the exhaust and intake valves closed begins the compression stroke. Near the top of the stroke the fuel/air mixture is ignited and causes the gases in the combustion chamber to expand. The power stroke begins as the gases expand and the piston begins its decent. At the bottom of the power stroke the exhaust valve opens and the piston begins its fourth stroke (or ascent) and pushes the spent fuel/air mixture or exhaust from the combustion chamber. At the top of this stroke the intake cycle begins and the entire sequence repeats itself.

At the same time the combustion sequence is taking place, another sequence is transpiring under the piston in the crankcase chamber of the engine. As stated previously, the crankcase chamber is an air pump. As with any air pump there must be a way of letting in and expelling air (or fuel/air mixture) from the air pump. This is accomplished by use of a rotary valve that is connected to the crankshaft in the YS engines. As the crankshaft turns, the rotary valve on the back of the engine also rotates. As the valve rotates, the open pie shaped area of the valve opens and closes fixed passages in the engine connected to the carburetor or intake manifold. The function of the crankcase chamber is to move the fuel/air mixture through the engine. It draws a fuel/air mixture into the chamber through the carburetor, pressurizes it and then expels it into the intake manifold. This is done by the up and down movement of the piston. Starting at the top of the intake stroke, the piston begins its descent. At this time the rotary valve opens the port into the intake manifold leading to the intake valve. As the piston descends it pushes the fuel/air mixture from the crankcase chamber into the intake manifold. As the piston reaches the bottom of the intake stroke the rotary valve closes the port to the intake manifold and opens the port to the carburetor. As the piston ascends during the compression stroke the piston also draws air

through the carburetor and mixes it with fuel. This fuel/air mixture enters the crankcase chamber. As the piston descends for the power stroke the rotary valve closes to the carburetor and opens once again to the intake manifold. This allows a fuel/air charge to enter the intake manifold. Remember though that we are in the power stroke and the intake valve is still closed. This charges the intake manifold with a fuel/air mixture. As the piston ascends during the exhaust stroke, the rotary valve is opened again to the carburetor and closed to the intake manifold. As exhaust gases are being expelled from the combustion chamber, the crankcase chamber is drawing in still another charge of fuel/air. Now the piston descends for the intake stroke and the rotary valve to the carburetor closes and simultaneously opens to the intake manifold. There are now two fuel/air charges entering the combustion chamber during the intake stroke. Hence the term "supercharged" applies to the YS engine! In summary, the combustion chamber is going through four cycles but the crankcase chamber is going through two cycles and creating a pressurized condition in the intake manifold.

The fuel delivery system is unique. The YS engines use a pressurized system to control the flow of fuel to the carburetor. The beauty of a pressurized fuel system is that, no matter what attitude the airplane assumes, the fuel delivery is not dependent on gravity or a slight pressure from the exhaust system to deliver fuel. During long vertical maneuvers the engine is supplied fuel constantly. Subsequently, the engine doesn't lean during verticals or become rich during dives. Because the fuel system is pressurized, no portion of the system is vented to the atmosphere. The pressure for the system comes from the crankcase chamber. There is a small port in the crankcase chamber that allows pressure from the crankcase chamber to be directed back to the fuel tank. As explained previously, the crankcase chamber develops pressure and then vents it into the intake manifold. During the up and down movement of the piston, there are times when the crankcase chamber is pressurized and also under a slight vacuum. The pressurize fuel delivery system can't work if there is any vacuum induced into the system. Therefore,

the YS has an in-line check valve that prevents the fuel system from losing pressure. The pressure that builds up in the fuel tank will never exceed the pressure developed in the crankcase chamber. However, the engine might not need all the fuel pressure developed from the crankcase chamber; hence the need for a pressure regulator on YS engines.

The regulator regulates the flow of fuel to the carburetor depending upon operating conditions. The regulator consists of a clear rubbery diaphragm, a small spring, a plunger, a brass threaded housing and a small, whitish rubbery tapered valve. The regulator is enclosed in an aluminum housing located near the front and bottom of the engine. There is a small chamber cast into the engine housing over which the regulator is fastened. Pressure from the crankcase chamber is delivered to this small chamber via a small port. On top of this small chamber is the diaphragm. The regulator housing holds the diaphragm between the small chamber in the engine housing and another small chamber in the regulator housing. Fuel from the fuel tank enters the small chamber in the regulator housing between the diaphragm and the seated, tapered valve. When the tapered valve is opened fuel flows to the throttle body. The tapered valve is held in place by a plunger that rests against the diaphragm. The plunger pushes the tapered valve open when there is pressure against the diaphragm. The tapered valve is held shut by a small spring. The spring compression controls the amount of fuel that will flow to the carburetor. The visible brass screw in the regulator housing controls the amount of pressure applied by the spring to the tapered valve. Here's how the regulator actually works. Pressure from the crankcase chamber pushes against the diaphragm via an air port in the engine case. The plunger pushes the tapered valve open and allows fuel to pass to the carburetor. If there is too much fuel flowing to the carburetor (or the engine is running rich at idle), the brass screw is turned into the housing (or clockwise), thereby increasing the spring compression against the tapered valve. If there is not enough fuel flowing to the carburetor (or the engine is running lean at idle), the brass

screw is turned out of the housing (or counterclockwise) decreasing the spring compression and allowing the tapered valve to open sooner, thereby allowing more fuel to flow to the carburetor.

The fuel system also supplies the lubrication for the YS engine. The lubricating oil in the fuel is distributed to all the moving engine parts via the fuel delivery system. It is important to use a quality grade fuel for the engine. YS-Futaba recommends using 2-cycle fuel with a 20% oil content. Consider using one of these quality fuel suppliers and their particular product for use in your engine:

#### Magnum Fuel:

Premium Blend 1  
Standard Blends

#### Powermaster

20-20 Blend

#### Morgan Fuels

Cool Power (20% nitro)  
Omega (20% nitro)

The YS engine does not require a tuned exhaust system to extract power from the engine. The YS engine requires nothing more than a straight pipe approximately 2" long connected to the exhaust port of the cylinder head. However, this type of exhaust system is loud and will not meet the sound requirements established in the AMA or FAI rule book. So, a muffled pipe should be fastened to the engine.

Supercharging the fuel/air mixture makes the YS unique. Supercharging on the standard YS engine is not as noticeable as with the YS-120AC, YS-120SC, YS-140FZ and YS-410L. These engines have an "air chamber" incorporated into the intake system. This "air chamber" system replaces the simple intake manifold or intake tube found on the standard YS. The "air chamber" is of much larger volume than the intake tube and allows the fuel/air mixture to be compressed prior to being injected into the compression chamber. Remember that the crankcase chamber functions on a 2-cycle

principle and the combustion chamber functions on a 4-cycle principle. This allows the fuel/air mixture to be compressed twice by the pressure in the crankcase chamber for every one combustion cycle. The air chamber on the YS-120AC is a metal box approximately 1"x1"x1" on the back of the engine. It replaces the intake tube that connects the carburetor and the intake port in the cylinder head. The air chamber in the YS-120SC, YS-140FZ and YS-140L is actually an internal air chamber formed by the valve cover and adjacent void area in the head. By not replacing the intake tube with a large air box (as with the YS-120AC) YS was able to decrease the weight of the engine by approximately two ounces. A substantial savings considering it is removed from the farthest point from the center of gravity of the airplane.

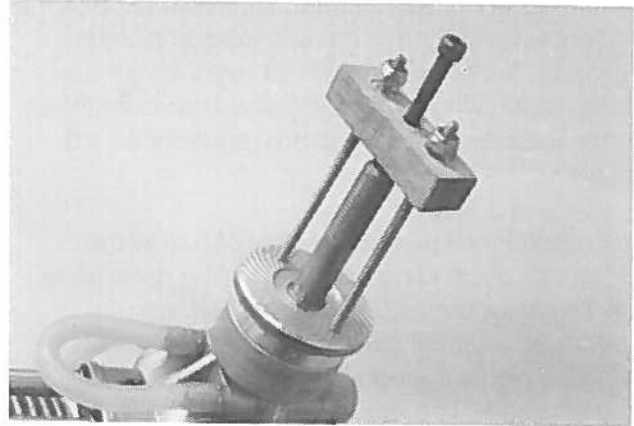
## ENGINE MAINTENANCE-DISASSEMBLY

Every once in a while you will be required to disassemble your engine. You could disassemble it to perform routine maintenance or to thoroughly clean it after the airplane ran off the end of the runway and the front of the airplane and engine were buried in dirt. Before you begin to disassemble your YS engine, keep a few thoughts in the forefront of your mind: all pieces should be removed with little effort; if you find resistance in removing any part, *stop*. Examine these instructions again or study the blow-up diagram of the engine. There's a good chance you have not removed all the necessary bolts or components that will allow you to remove the component you wish to remove.

### DRIVE WASHER

**11.01.** Remove the drive washer from the front of the engine. The drive washer slides on and off the crankshaft very easily when the engine is new. However, after a prop has been installed and secured in place, the back of the drive washer "mushrooms," by binding against the crankshaft and is difficult to remove by hand. It can be removed by either a drive washer removal tool or

by building a removing tool as we have shown in the photo.



Home made Drive Washer Remover

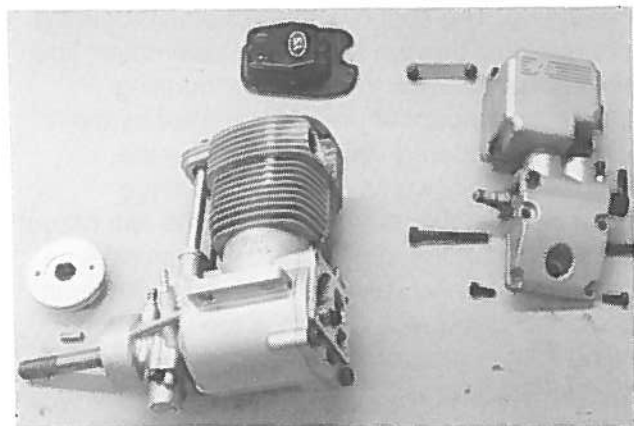
### VALVE COVER, CARBURETOR, INTAKE TUBE AND CYLINDER HEAD

**11.02.** Remove the bolts and metal strap that secure the air box to the valve cover (if engine has an air box).

**11.03.** Remove the valve cover bolts and valve cover. Be careful not to damage the valve cover gasket.

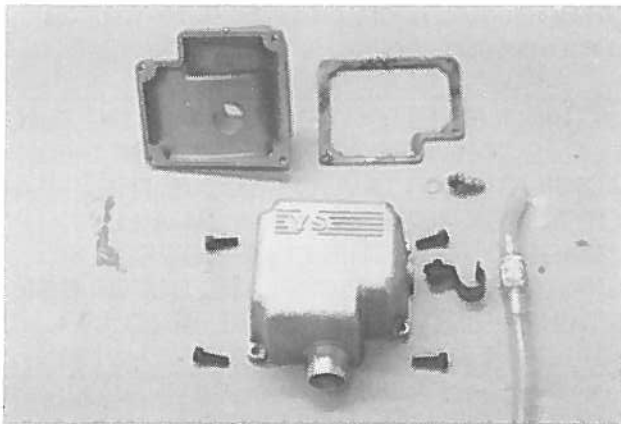
**11.04.** Remove the throttle body bolts securing the carburetor to the engine.

**11.05.** Remove carburetor and intake tube (or air box).



Carburetor, Valve Cover & Air Box Removed from Engine

**11.06.** Disassemble the air box (if the engine is an AC).



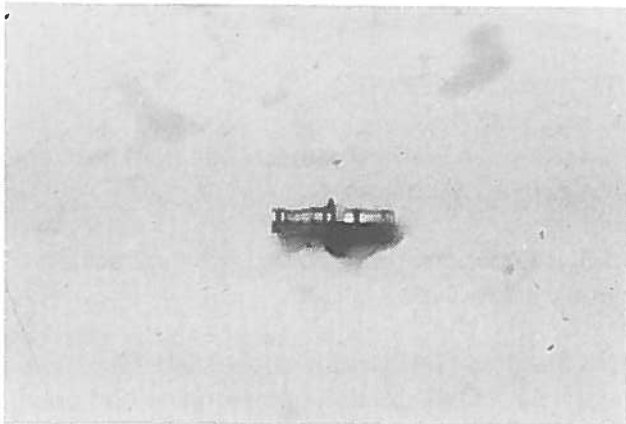
Air Box w/ Check Valve-Disassembled

**11.07.** Remove the cylinder head bolts and cylinder head. When the cylinder head is removed the push rod tubes and push rods may also be removed.

**11.08.** Remove the fuel nipples from the engine case.

## CARBURETOR

**11.09.** Remove the needle valve, needle valve housing and needle valve spring retaining clip.



Needle Valve Socket w/ O-Rings

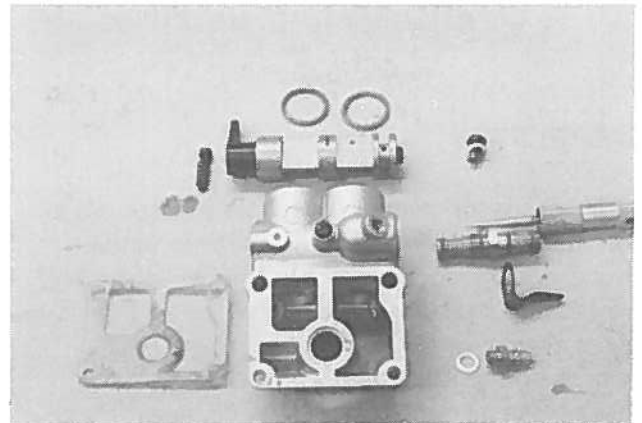
**11.10.** Remove the carburetor barrel retaining screw. This is the Phillips head screw on the front of the carburetor case.

**11.11.** Remove the plastic throttle arm from the end of the carburetor barrel.

**11.12.** Back out the barrel stop screw until the carburetor barrel slides out.

**11.13.** Remove the fuel nipple from the carburetor case.

**11.14.** Remove the small Phillips screw from the front of the case near the needle valve housing that exposes one of the fuel ports.



Carburetor Disassembled

## REGULATOR

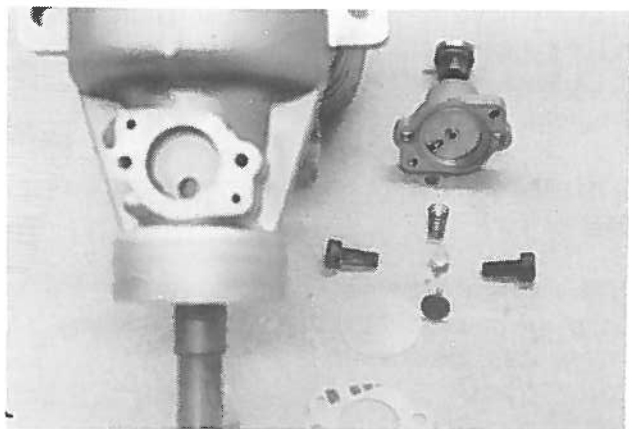
**11.15.** Remove the two bolts holding the regulator to the engine case.

**11.16.** Remove the regulator.

**11.17.** Remove the brass screw from the regulator body.

**11.18.** Remove the plunger spring.

**11.19.** Remove the whitish clear rubbery plug valve carefully, using a pair of forceps. This plug valve is small and very important. Handle it gently and don't damage it as it is removed. When the plug valve is removed, the brass actuator will drop out the other side. Be prepared to catch this actuator when the plug valve is removed.

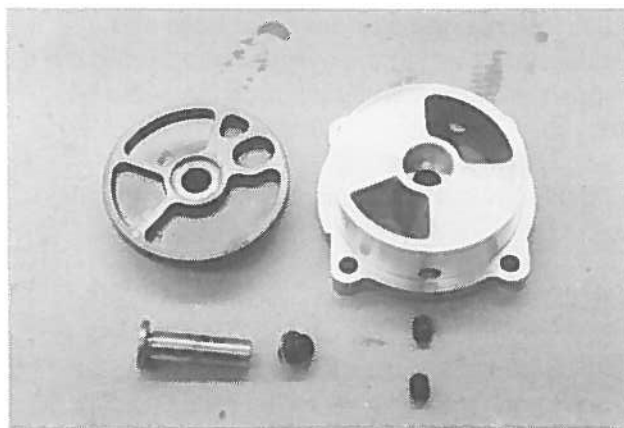


Regulator Disassembled

**11.23.** Remove each Allen screw. With the rotor disk retainer pin bolt removed and two Allen screws removed gently press the brass rotor disk retainer pin from the back of the engine.

**WARNING! IF YOU DO NOT REMOVE THE TWO ALLEN SCREWS FROM THE INSIDE OF THE BACKPLATE AND TRY TO REMOVE THE ROTOR DISK RETAINER PIN, YOU WILL DAMAGE THE PIN. THIS PIN IS NOT SOLD SEPARATELY. THE BACKPLATE, ROTOR DISK, RETAINER PIN AND BOLTS ARE SOLD AS A UNIT ... A VERY EXPENSIVE UNIT!**

Remove the rotor disk from the backplate. Remove the bolt from the back of the rotor disk retainer pin.

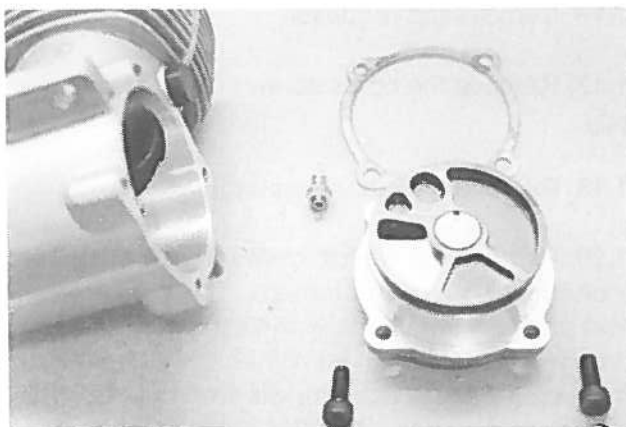


Backplate Disassembled

## BACKPLATE

**11.20.** Disassembling the backplate assembly is not really necessary for routine maintenance. Operating tolerances of the backplate assembly are critical for proper operation of the engine. If you are at all unsure of your abilities, it is recommended that you don't disassemble the backplate assembly. If however, disassembly is necessary, measure the factory clearance between the backplate and the rotary valve prior to disassembly so you have an idea of the required clearance during assembly.

**11.21.** Remove the backplate from the engine case.



Backplate Removed From Engine Case

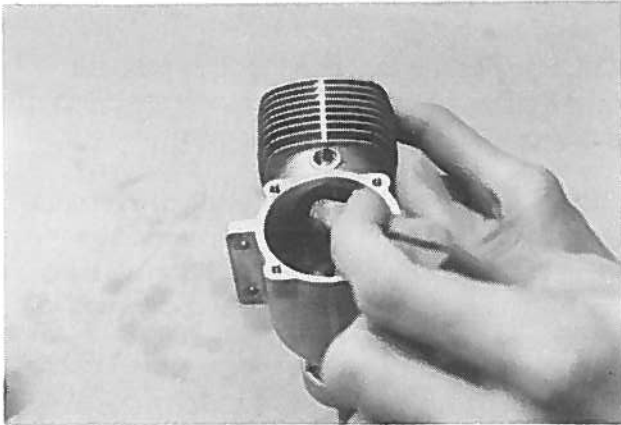
**11.22.** On the side of the backplate there is a small hole with two Allen screws inside one pushing on top of the other.

## PISTON AND SLEEVE

**11.24.** Remove the Phillips head bolt from the front of the engine cylinder area.

**11.25.** Remove the rubber plug from the back of engine cylinder area.

**11.26.** Remove the cylinder sleeve. Insert a wooden stick in the bottom of the engine and push the bottom of the cylinder sleeve up about 1/8".

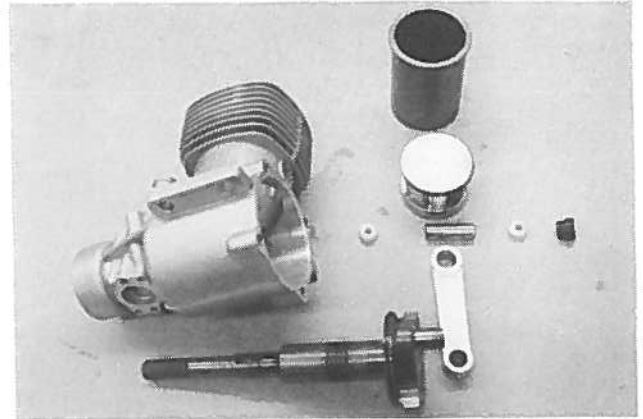


Cylinder Sleeve Being Removed With Pressure From Wood Dowel

**11.27.** Grasp the top of the protruding cylinder sleeve and remove it from the case. Be very careful performing the next few steps or risk damaging the piston. Gently rotate the crankshaft until the piston is positioned at bottom dead center. Look in the hole where the rubber plug on the back of the engine was removed. There is a Teflon wrist pin retainer in the front and back of the piston. You should see the white Teflon wrist pin retainer through the hole in the engine case in the rear of the piston. Align the Teflon wrist pin retainer with the hole. Insert a pushrod into the hole in the front of the engine where the Phillips screw was removed. Gently slide it through the hole in the Teflon wrist pin retainer in the front of the piston and against the backside of the wrist pin. Press the Teflon wrist pin retainer in the back of the piston and wrist pin through the hole in the back of the case very gently.

**11.28.** With the wrist pin pushed out and the push rod still through the piston and case, invert the engine so the top of the piston is pointed at the ground. Gently remove the push rod and catch the piston as it falls from the case. Do not let the piston fall to a hard surface, or it might sustain irreparable damage. If this happens, it's time to buy a new piston.

**11.29.** Reach in the back of the case and remove the connecting rod.



Piston and Sleeve Disassembled

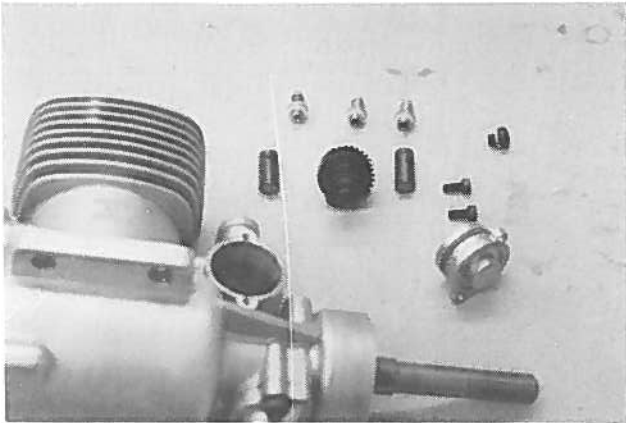
## CAMSHAFT

**11.30.** Remove the camshaft cover bolts.

**11.31.** Remove the camshaft cover. There is a rubber seal on the cover. This is a tight seal and inhibits easy removal. To remove the cover, gently twist and pull the cover from the case.

**11.32.** Move the camshaft lifters out of the way. With the camshaft cover removed, gently reach in with a small screwdriver and push the exhaust lifter up into the case. With the lifter up in the case, tip the engine towards the ground and cover the camshaft hole with your hand. Catch the camshaft as it falls out of the hole.

**11.33.** Remove the lifters from the case. With the camshaft removed, insert a pushrod into the exhaust lifter and push it down into the camshaft cavity.



Camshaft, Lifters and Cover Disassembled

Tip the engine towards your hand and catch the lifter as it falls from the camshaft cavity. Repeat this process for the intake lifter.

## CRANKSHAFT

**11.34.** Remove the crankshaft.

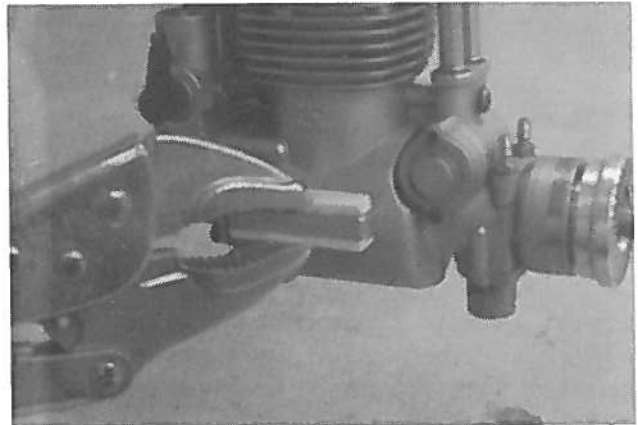
**DO NOT REMOVE THE CRANKSHAFT UNTIL AFTER THE CAMSHAFT HAS BEEN REMOVED. IF YOU TRY TO REMOVE THE CRANKSHAFT WITH THE CAMSHAFT STILL INSIDE THE ENGINE CASE, THE CAMSHAFT WILL BE DAMAGED, AND THE CAMSHAFT IS A VERY EXPENSIVE PART OF THE ENGINE!**

To remove the crankshaft, gently tap on the front of the crankshaft with a block of wood or other soft material that will not damage the crankshaft threads. The SC crankshaft requires more effort to remove the crankshaft because of the two crankshaft rings and their interference with the crankcase. Rotate the two crankshaft rings so the grooves or openings in the rings are at the bottom of the crankcase. With your thumb, reach down through the top of the case and press down on the rings. Simultaneously, gently tap the end of the crankshaft. The crankshaft should fall out of the case.

## MAIN AND FRONT BEARING

**11.35.** Remove the rear bearing. This process requires either a bearing puller, a delicate touch with a propane torch or a toaster oven.

**11.36.** Using the torch and a heavy glove on your hand, heat the case on the outside around the area of the main bearing. You can also use a pair of Vice Grips and two scrap pieces of plywood to hold the case while you heat it.

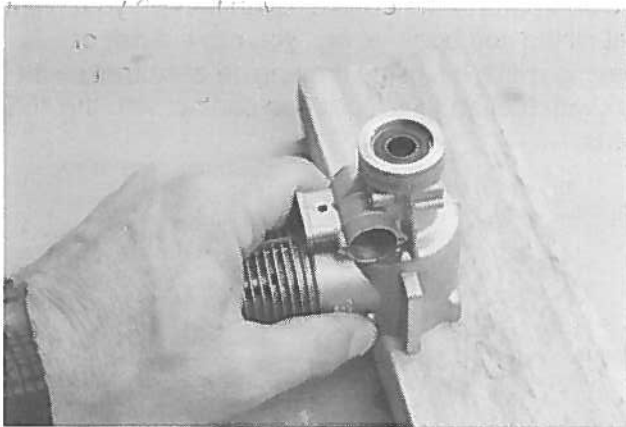


Vice Grips and Scrap Plywood Used To Hold The Engine Case

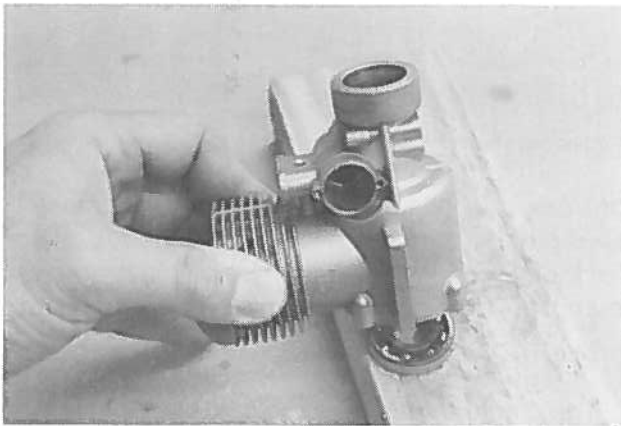
**11.37.** Move the case around in the flame of the torch to evenly distribute the heat near the bearing seat. Once heated, remove the case from the torch and quickly rap the back of the engine on a block of wood. The bearing should fall out.

**DO NOT RAP THE ENGINE ON ANY HARD MATERIAL. YOU MAY DAMAGE THE BACK OF THE MATING SURFACE OF THE ENGINE CASE.**

Another option is to heat the case in a toaster oven for one-half hour at 220°. Remove it from the oven (with gloves) and rap the engine on a block of wood.

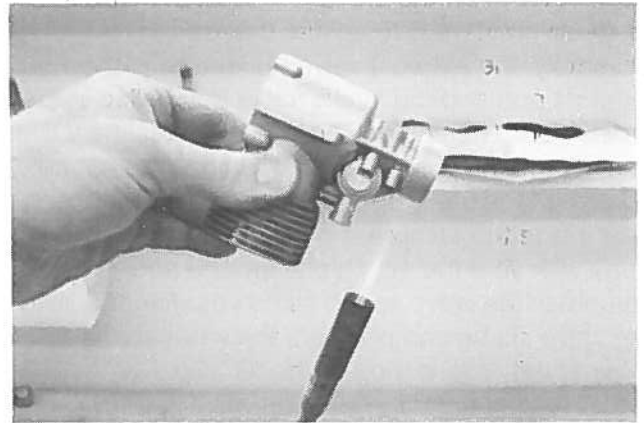


Striking Engine Case On A Soft Surface To Prevent Damage



Rear Bearing Removed From Engine Case

**11.38.** Remove the front bearing. This procedure requires a bearing puller or a delicate touch with a propane torch and a piece of 5/8" hardwood dowel. Using the torch a heavy glove on your hand or a pair of Vice Grips, heat the case on the outside around the area of the front bearing. Move the case in the flame of the torch to evenly distribute the heat.



Heating The Engine Case Around The Front Bearing

**11.39.** Once heated, remove the case from the torch and insert the hardwood dowel inside the engine to the back of the front bearing, and quickly rap the hardwood dowel on a block of wood. The bearing will pop out the front of the case.



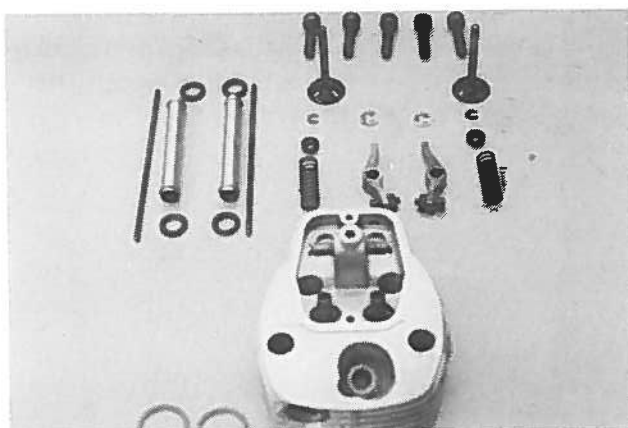
Pushing Out Front Bearing Using A Wooden Dowel

## CYLINDER HEAD

**11.40.** Remove the rocker arms from the cylinder head. There are little "E" clips that are used to hold the rocker arms on their shafts. Push them out using a wide-tip screwdriver. Be careful, use safety glasses and keep an eye on the clip. Sometimes they have a tendency to spring a short distance. Once the clips are removed, the rocker arms will slide off their shafts.

**11.41.** Remove the valves, valve springs and valve spring retainers. Before you remove the valves, valve springs or valve spring retainers, scratch an

"E" and an "I" on the exhaust and intake valves respectively. This is to ensure that during assembly, the exhaust valve is installed in the exhaust port and the intake valve is installed in the intake port. There is a "C" clip that retains the valve spring onto the valve stem. To remove the "C" clip, compress the valve spring. Hold the valve in the seat inside the compression chamber area of the head with your thumb. Reach around and compress the valve spring using your fingers. With the valve spring compressed, the valve spring retainer will drop, exposing the "C" clip. Remove the "C" clip and gently relax the valve spring. The valve spring retainer and valve spring will slide off the valve stem and the valve can then be removed from the head.



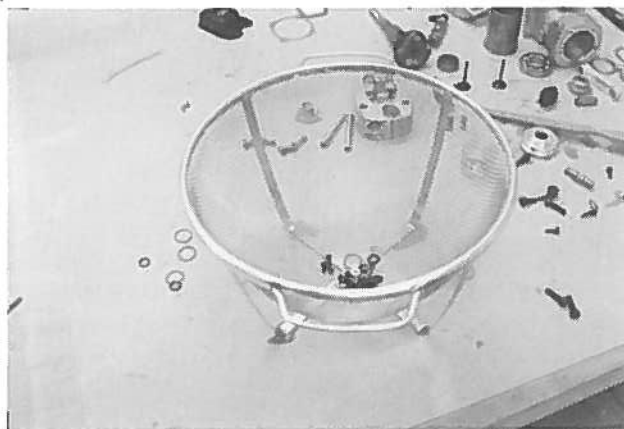
Cylinder Head Disassembled

The engine is now totally disassembled.

## ENGINE MAINTENANCE-ASSEMBLY

Before engine assembly it is important to clean all its components. You can be sophisticated and use a parts cleaning tub with a pump. Or you can use the bottom of a bleach container. We cleaned our engines for many years with just the bottom of a gallon plastic bottle, alcohol and a toothbrush, and it worked just fine. We have moved up a little and have purchased a parts cleaning tub with a small pump. It makes it easier, but not any more effective. It is important to clean the engine with industrial grade detergent and water or alcohol. Never use a petroleum-based product to clean your engine. Petroleum based products (i.e. gasoline, kerosene, solvent) will destroy some of

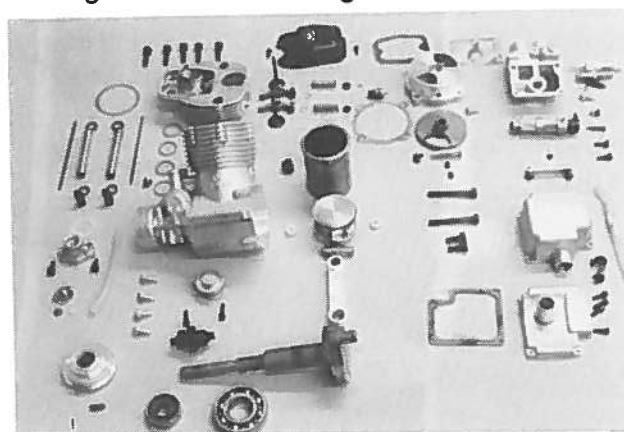
the soft parts in the engine. Even though you might get all the components dry, you run the risk of leaving a little bit inside the engine case that might mix with fuel and then come in contact with the soft parts.



Kitchen Sieve (With A Tight Weave) Used To Clean And Retain Parts

Don't use solvent, kerosene or any petroleum based product to clean the engine. Even residue from these products will destroy the "soft" parts of the engine. These parts includes, but is not limited to:

- The diaphragm;
- Pushrod tube "O" rings;
- Fuel nipple gaskets;
- Plastic carburetor gaskets;
- Regulator screw "O" ring.



A Totally Disassembled YS Engine Cleaned and Ready For Assembly

After thoroughly cleaning all the parts, dry them with a lint-free rag and/or compressed air. Make sure all ports throughout the engine case,

carburetor and regulator are clear of any debris or moisture. Compressed air does the best job of cleaning out each port.

To assemble the engine you must have a lubricant to apply to all the moving engine pieces. This will aid in assembly and give the engine protection during the first start-up. A castor oil or synthetic based lubricant is the best. Don't use any lubricant that will react with silicone; the diaphragm inside the regulator is made with silicone, and will disintegrate if a petroleum-based lubricant is used. WD40 is a silicone-based lubricant. Don't use it to lubricate your engine during assembly.

## CARBURETOR

**11.42.** Install the small Phillips screw in the front of the case near the needle valve housing that exposes one of the fuel ports.

**11.43.** Install the fuel nipple in the carburetor case.

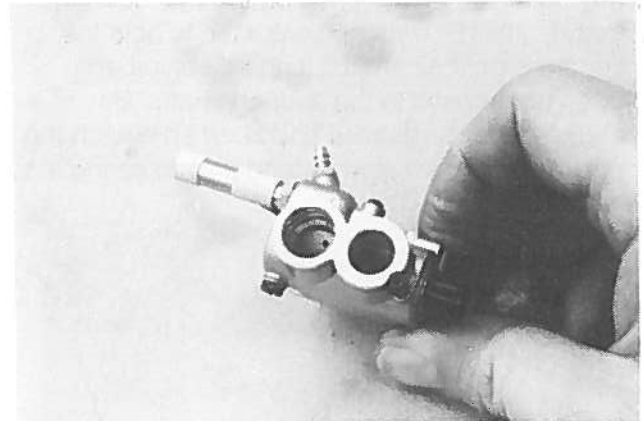
**11.44.** Install the carburetor barrel retaining screw. This is the Phillips head screw located on the front of the carburetor case.

**11.45.** Install the plastic throttle arm on the end of the carburetor barrel.

**11.46.** Screw in the barrel stop screw until the carburetor barrel just rolls shut.

**11.47.** A good way to check this is to put your mouth over the carburetor opening and blow into the port. Then gently open the throttle arm. When you can feel air pass through the port when the throttle arm is just opened and no air passes when the throttle arm is closed against the stop screw, the stop screw is adjusted correctly.

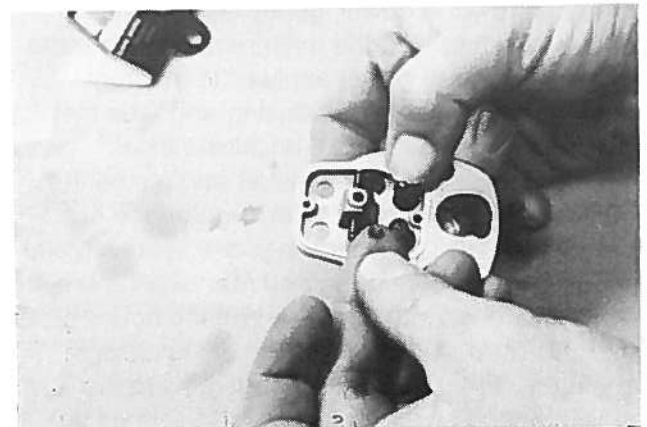
**11.48.** Install the needle valve, needle valve housing and needle valve spring retaining clip.



Carburetor Assembled

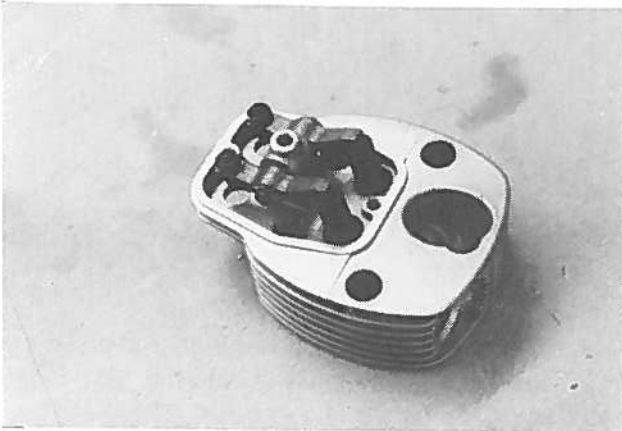
## CYLINDER HEAD

**11.49.** Install the valves, valve springs and valve spring retainers. Insert the valve with the "E" scratched on the face in the exhaust. There is a "C" clip that retains the valve spring on the valve. To install the "C" clip, compress the valve spring. Hold the valve in the seat inside the compression chamber area of the head with your thumb. Using your fingers, reach around and compress the valve spring. With the valve spring compressed, install the valve spring retainer and "C" clip in the groove in the valve stem. Then gently relax the valve spring. The valve spring retainer and valve spring are now installed. Check the installation by inspecting the "C" clip to ensure it is properly installed. Also, check the assembly by pressing down on the top of the valve stem. Everything should feel smooth as the valve is moved up and down.



Installing "C" Clips on Valve Stems

**11.50.** Install the rocker arms on the cylinder head. There are little "E" clips that are used to hold the rocker arms on their shafts. Insert them into the appropriate grooves in the support shafts. Be careful, use safety glasses and keep an eye on the clip. Sometimes they have a tendency to spring a short distance.

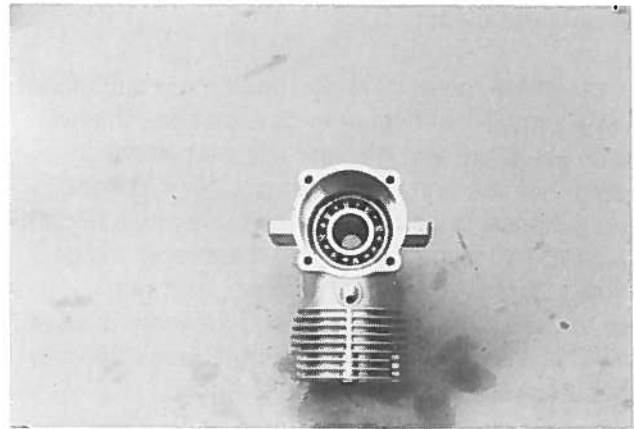


Cylinder Head Assembled

## MAIN AND FRONT BEARING AND CRANKSHAFT

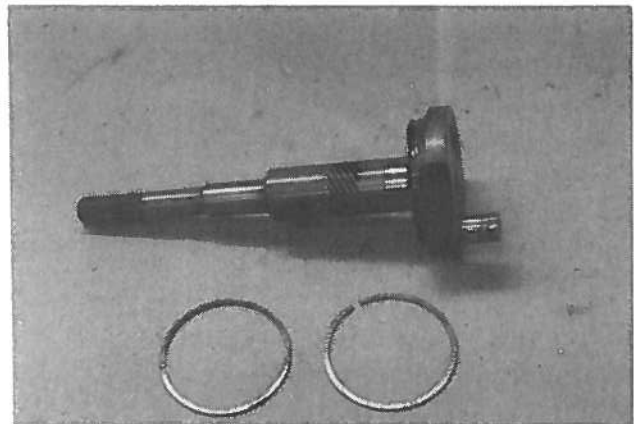
**11.51.** Install the rear bearing, crankshaft and front bearing at one time. Slide the rear bearing onto the crankshaft and apply oil to the main bearing. Using the torch and a heavy glove on your hand, heat the case on the outside around the area of the main and front bearing. Move the case in the flame of the torch to evenly distribute the heat. Once heated, remove the case from the torch,. Slide the crankshaft and rear bearing into the case pressing the main bearing into the housing in the case. Using a hardwood dowel, gently tap the back of the crankshaft to seat the main bearing. While the engine case is still warm, apply oil to the front bearing and front bearing housing and slide the bearing into the crankshaft. Install the thrust washer, a propeller, drive washer and nut on the end of the propeller drive shaft. Tighten the nut until the front and main bearings are seated. Make sure both the front bearing and rear bearing are installed as deep into the case bearing housings as possible. Then spin the propeller. It should spin very freely. If there is any binding, remove the crankshaft and check to see if both bearings are installed correctly. If there is any binding take the

assembly apart find out why there is a problem and then try it again.

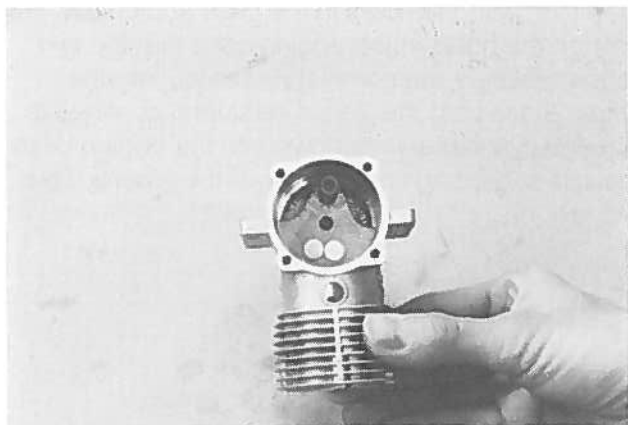


Rear Bearing Installed In Engine Case

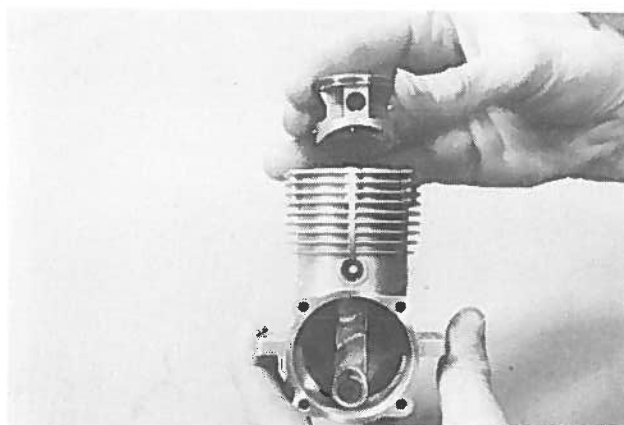
**11.52.** If you are working with an "AC" engine, install the crankshaft rings in the crankshaft groove. These are the two rings that seal the front of the engine from the rear crankcase (this improves the engine's ability to build up supercharging pressure). Then install the crankshaft into the engine.



Crankshaft Rings and Crankshaft



Crankshaft Installed In Engine



Connecting Rod Aligned With The Hole In The Engine Case

## PISTON AND SLEEVE

**11.53.** Install the connecting rod. Look very closely at the crankshaft end of the connecting rod. This is the end with two holes or ports for fuel/oil to lubricate the connecting rod journal.



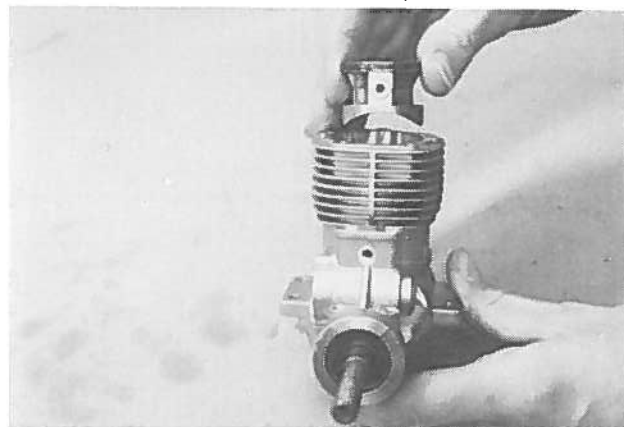
Connecting Rod With Beveled Journal

One side of the journal is beveled more than the other side. This bevel is subtle, but very important. The beveled side of the connecting rod mates with the rear of the crankshaft. If the connecting rod is installed backwards, after starting, your engine will overheat and possibly stop.

Rotate the crankshaft to bottom dead center and install the connecting rod on the crankshaft journal.

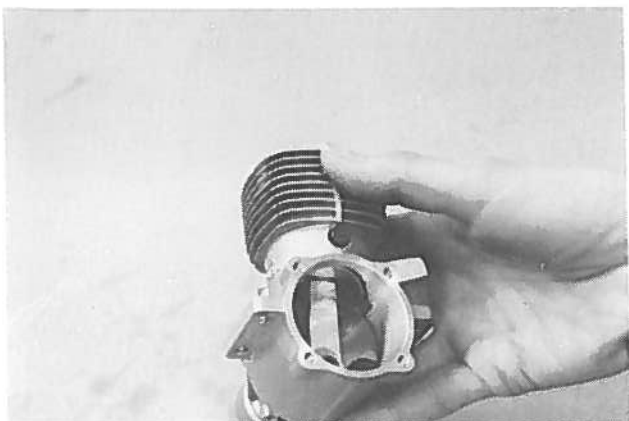
**11.54.** Rotate the crankshaft and connecting rod until the connecting rod piston journal hole is aligned with the engine case hole.

Place one Teflon wrist pin retainer in one of the ends of the wrist pin hole in the piston.



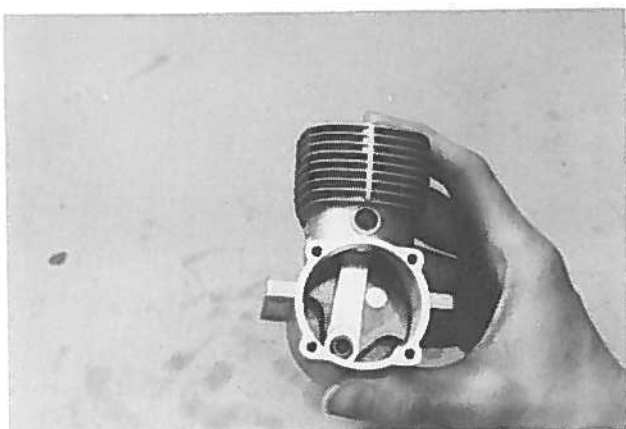
Inserting Piston w/ Installed Teflon Retainer Into Engine Case

Gently insert the piston into the engine case over the end of the connecting rod, with the Teflon retainer pointed towards the front of the engine. Align the wrist pin hole in the piston with the large hole in the rear of the engine case. Lubricate the wrist pin and insert it through the engine case hole into the piston. Install the wrist pin with the hole end towards the front of the engine.



Wrist Pin Being Installed Into Piston And Connecting Rod

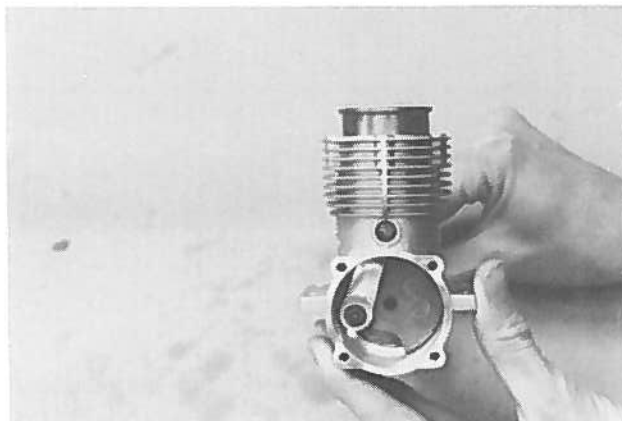
Install the other Teflon retainer into the piston and gently press it against the wrist pin and seated into the piston.



Remaining Teflon Retainer Installed Through Engine Case Into Piston

**11.55.** Install the cylinder sleeve. Apply lubricant to the inside and outside of the cylinder sleeve. Smear it around with your finger to give it a light coat of oil on the entire inside and outside of the sleeve. Rotate the crankshaft until the piston is at the top of its stroke. Apply lubricant to the perimeter at the top of the piston. Rotate the crankshaft until the piston top is about a centimeter below the top of the engine case. Gently slide the cylinder sleeve into the engine case. While holding the crankshaft still, rotate the sleeve and gently slide it down over the top of the piston. Be careful to gently slide and rotate the sleeve over the piston ring. Once the piston and ring are inside the cylinder sleeve, slide the cylinder sleeve past the two Teflon retainers. If you feel resistance, align

the piston with the holes in the case and check through the holes in the engine case that the two Teflon retainers are completely seated into the piston. Once past the Teflon retainers, continue to slide the cylinder sleeve down into the engine case until it is seated against the top of the engine case.



Piston Sleeve Installed Inside Case Over Piston Ring and Teflon Retainers

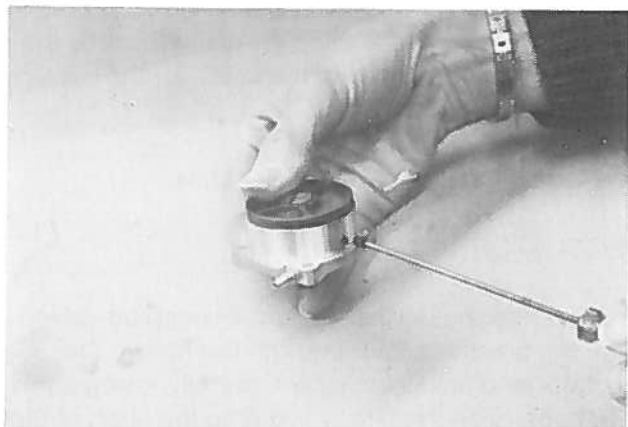
**11.56.** Install the rubber plug in the back of the engine cylinder area.

**11.57.** Install the Phillips head bolt, with a plastic washer, in front of the engine cylinder area.

## BACKPLATE

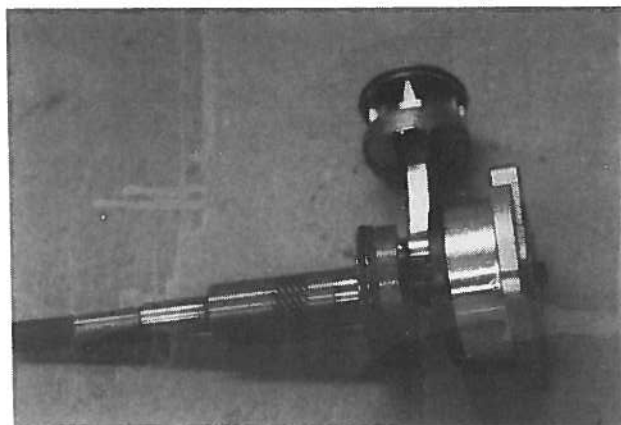
**11.58.** Install the rotor disk onto the backplate. Insert the brass rotor disk retainer pin into the rotor disk and then into the backplate. Align the pin so the Allen screws will seat against the flat spot on the retainer pin. Install one Allen screw in the hole in the backplate and gently tighten it against the retainer pin. Adjust the backplate so there is a small gap between the backplate and the rotor disk. During operation, this gap is sealed with the fuel mixture to retain pressure in the bottom of the engine case. This is a critical gap. If the gap is too small, the disk will expand during operation and bind against the housing, causing the engine to overheat and quit. If the gap is too big, the pressure will not be sustained in the lower engine case and the engine will lack power. The proper gap is achieved when the rotor rubs very lightly against the backplate. The factory does not give a specification for the clearance, but we have found that a .005" to .006" clearance seems to work well

(or use the clearance you determined when you disassembled the engine). Once the gap is set, tighten the first Allen screw securely against the retainer pin. Then screw the second Allen screw into the same hole and tighten it against the first Allen screw.

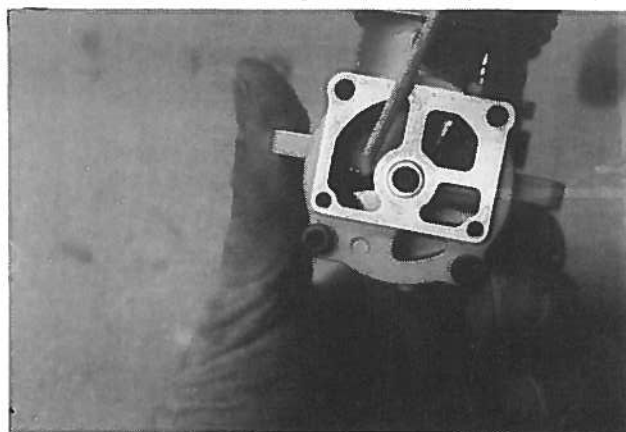


Set Screws being Installed In The Backplate

**11.59.** Install the backplate onto the back of the engine case. Rotate the crankshaft until it is at bottom dead center. Install the backplate gasket on the backplate. Rotate the rotary valve in the backplate until the impression in the valve for the crankshaft journal is also at bottom dead center. Install the backplate/rotary valve into the back of the engine at the same time, aligning the rotary valve impression with the crankshaft journal. Once you've installed the backplate/rotary valve, check to ensure the rotary valve is connected to the crankshaft. Look into one of the back ports of the engine. Rotate the crankshaft and watch the rotary valve. If its movement mimics the movement of the crankshaft, all is well. If the two don't move together, disassemble and realign.



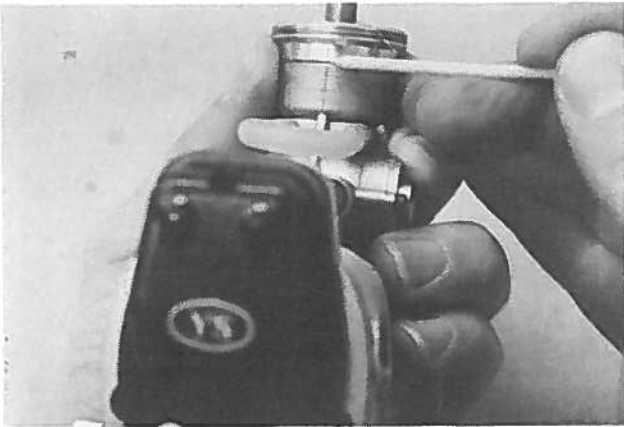
Interface Of Crankshaft, Connecting Rod, Piston Rotary Valve & Backplate



Checking Rotary Valve Rotation Through The Back Of The Engine

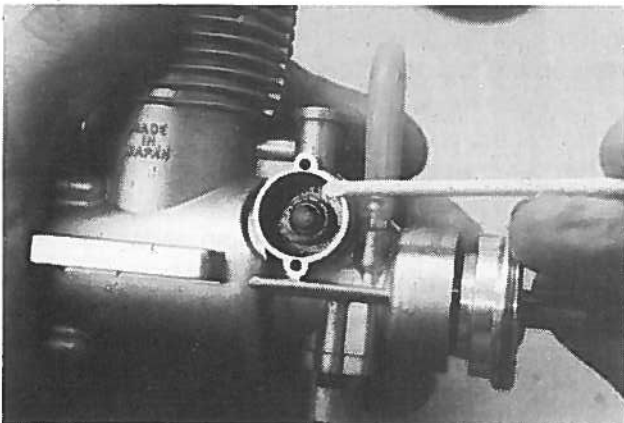
## CAMSHAFT

**11.60.** Install the shaft key and drive washer on the front of the crankshaft. Rotate the crankshaft until the mark on the drive washer is aligned with the seam on the top of the engine case. If you compare the mark on the drive washer and the position of the piston in relationship to TDC, they are not the same. There is a 5° difference between them. The thrust washer/engine case alignment should be used for optimum engine performance. The later model thrust washers don't have the alignment mark on them. In this case, obtain an older thrust washer to align the cam; once the cam is installed, remove the old thrust washer and install the later model thrust washer.



Drive Washer Mark Aligned With Engine Case Seam

**11.61.** Drop lubricant into the camshaft bearing inside the engine case. Examine the camshaft and find a small impression on one side of the camshaft gear. This impression faces toward the opening of the cavity. Insert the camshaft into the camshaft cavity, noting that the camshaft will twist as it seats. The camshaft gear meshing with the crankshaft gear causes the twisting. Install the camshaft so the impression points vertically towards the top of the engine. This might take a few tries to get the camshaft to engage the correct crankshaft gear tooth. Patience and a good pair of forceps will help you accomplish this task. You might notice that the cam does not align exactly to the top of the engine. It is okay for the cam mark to align at the "12:00" or "12:30" position, but don't align the dot with the "11:00" position.



Camshaft Installed With Impression Up

**11.62.** Drop lubricant into the camshaft bearing in the camshaft cover and install. There is a rubber

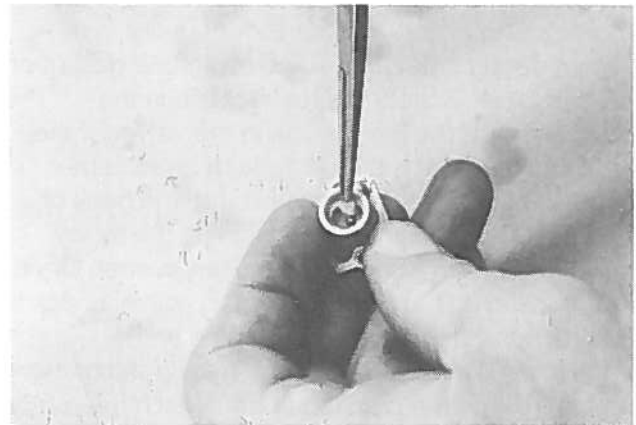
seal on the cover. Apply lubricant to the rubber seal. Install the camshaft cover by gently twisting the cover into the case.

**11.63.** Install the lifters. Drop lubricant into each lifter hole onto the camshaft lobe and the sides of the lifter holes. Lubricate the lifters and slide them into the holes with the solid side down towards the camshaft and the end with the holes for the pushrods pointed up.

**11.64.** Install the camshaft cover bolts.

## REGULATOR

**11.65.** Install the whitish, clear rubbery plug valve. Slide the brass actuator through the hole in the regulator and hold it in place. Carefully, using a pair of forceps, slide the plug valve onto the shaft of the brass actuator on the opposite side of the regulator.



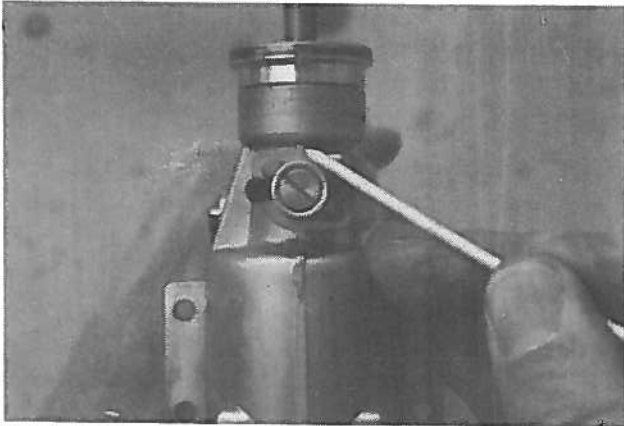
Plug Valve Being Installed on Actuator Shaft

**11.66.** Install the plunger spring on top of the plug valve. Orient the small end of the spring over the plug valve.

**11.67.** Install the brass screw in the regulator body. Check to make sure the large diameter end of the plunger spring is pointing towards the brass screw.

**11.68.** Install the regulator, regulator gasket and diaphragm onto the engine case. Make sure the molding on the regulator case faces towards the front of the engine.

**IF YOU INSTALL THE REGULATOR BACKWARDS, THE ENGINE WON'T RUN.**



Regulator Installed With Case Molding Forward

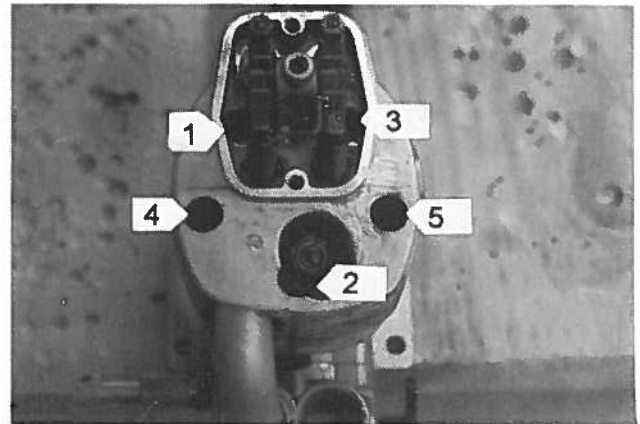
**11.69.** Install the two bolts holding the regulator to the engine case.

### **VALVE COVER, CARBURETOR, INTAKE TUBE AND CYLINDER HEAD**

**11.70.** Install the fuel nipples into the engine case.

**11.71.** Install the push rod tubes, push rods, cylinder head and cylinder head bolts. First install the "O" rings for the pushrod tubes in the cylinder head and the engine case. Insert the cylinder head bolts into the holes in the cylinder head. Install the cylinder head gasket. Install the pushrods into the case resting on the lifters. Slide the pushrod tubes over the pushrods. Do all of the following steps at once: Grasping the cylinder head in one hand and the engine case in the other, slide the pushrods through the holes in the head, align the pushrods with the rocker arms, position the cylinder head on the engine case and allow the cylinder head bolts to fall into the holes in the engine case, align the pushrod tubes in the "O" ring gaskets in both the head and the case. Once all is aligned, turn down the back cylinder head bolts first just a few turns. Check the alignment of the pushrod tubes in the "O" rings and the pushrods on the rocker arms. Turn down the other head bolts a few turns. Check alignment again. If all is well, continue to turn down the cylinder head bolts and check alignment. Take your time. Do not cut the "O" rings with the ends of

the pushrod tubes. If at any point during the process the alignment of the components is not correct, start over. When all the cylinder head bolts are secure (not tightened) and alignment is correct, then begin to tighten the cylinder head bolts. Tighten them in the pattern shown below. Increase the torque until all are tightened the same amount.



Cylinder Head Bolt Tightening Order

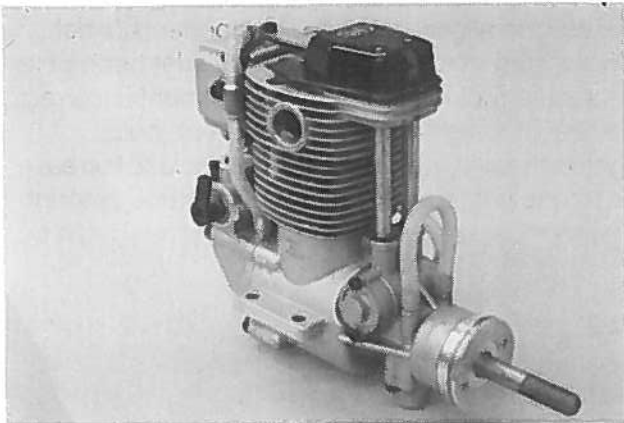
**11.72.** Install the carburetor, intake tube or air box and back plate.

**11.73.** Install the carburetor and back plate bolts.

**11.74.** Install the valve cover and valve cover bolts.

**11.75.** Install the air box bolt (if the engine has an air box). Make sure that the air box has two gaskets in it (no, the factory didn't make a mistake and put two into your new gasket set). Use green Locktite on the two bolts that hold on the air box. The air box moves around and the addition of the Locktite to the bolts helps them from becoming loose.

**11.76.** The engine is now totally assembled.



Totally Assembled YS Engine

## MAINTENANCE, ADJUSTMENTS AND BREAK-IN

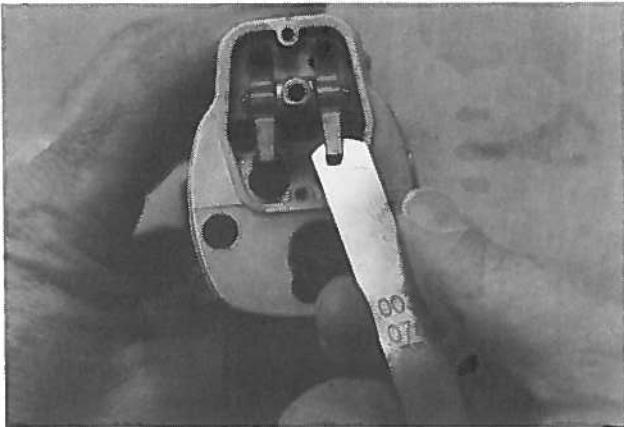
### 11.77. Break-in

Break-in of the YS engines is a relatively simple process. Before starting, check the brass regulator screw to ensure the top of the screw is even with the surrounding aluminum case. Install a prop that is approximately one inch less in diameter and a lower pitch than what you will eventually use on the engine. Rotate the main needle out of the case 1-3/4 turns. Fill the fuel tank with a quality fuel. Flip the prop (without the glow starter on the glow plug) with a gloved hand, approximately ten to fifteen times to distribute fuel through the engine and to ensure all moving parts are coated with fuel. Connect the glow driver and start the engine. It should be running slightly rich at this time. Give the engine a few minutes to warm up with a rich setting at approximately half speed. Adjust the needle setting so the engine is rich, but not excessively rich. Run the engine for a few minutes at full throttle. Now go fly with the engine set slightly rich.

Fly the plane with the small prop for approximately ten flights. After that, install the prop you wish to use, set the main needle to a slightly rich setting and start flying. To ensure longevity of your engine, always run the engine slightly rich - not excessively, just a 1/8th turn rich from optimum setting.

### 11.78. Adjustments

**Valves:** You should adjust the valves on a YS engine for every two hours of operation. Assuming flights last approximately 10-12 minutes each, two hours of running is approximately 10 to 12 flights. If you are flying frequently, this means you should adjust or check your valves twice a week. Valve adjustment is one of the most critical adjustments on the engine. If the valves are too loose or too tight, the engine will lose power, quit running or run lean, none of which is good for the engine. Adjusting the valves is not difficult and should become a part of the routine airplane maintenance. The valves should be set with a gap of .05 to .1 mm. This measurement is the gap between the rocker arm and the valve stem, and is measured with a feeler gage. Either adding strips to each other or finding one thickness that meets the gap requirement establishes the appropriate thickness of strips. Gently insert the feeler gauge strip(s) between the rocker arm and the end of the valve stem. The feel should be snug (not so tight that inserting the gauges raises the valve) but not so loose that you don't feel some pressure. It is definitely a "touch" - type adjustment. If you are not quite sure what you are doing, establish a feeler gauge thickness in the middle of the manufacturer's range. If the adjustment is a little loose or tight, the final outcome won't be that far off. *As you do more valve adjusting, the "feel" of what is the correct setting will become second nature.* Just practice, you'll get it. The most important point to remember is that you check the valve adjustment frequently. Also, it is better if they are a little loose rather than tight. However, as the engine wears, the pushrods make small indents in the rocker arms. If you use a feeler gauge the valves may be set too loose. An alternate way to adjust the valves is to loosen the locknut and gently screw the rocker arms screw down until it just touches the pushrod. Then back the screw up just a little less than 1/4 of a turn. Tighten the locknut and the adjustment should be very close. This method works well out at the field if you need to adjust the valves between flights.



Valves Being Adjusted

**Carburetor:** There is very little to adjust on the carburetor of the SF, AC and NC model engines. The regulator controls the fuel delivery and the only adjustment is the high-end needle.

**Main Needle:** The main needle controls the high speed fuel consumption on the engine on all the YS's. Adjust the main needle in conjunction with the low-end needle on the SC model engine. The initial setting on the needle valve should be approximately 1-1/2 turns out from being *gently* screwed into the needle valve housing. After you start and warm up the engine, gently advance the throttle to the full setting. At the initial setting the engine should be running rich. Begin to lean the engine by *slowly* rotating the needle valve into the housing. A 4-cycle engine responds more slowly than a 2-cycle engine to needle valve adjustments. Therefore, take your time. As you rotate the needle in, the engine will increase in speed until the mixture is too lean. At that point the speed of the engine will begin to decrease. At that setting, rotate the needle out about 1/4 turn (making the mixture richer) to ensure the engine is not running with too lean a mixture. Be extremely careful when adjusting the mixture towards the lean side. If the mixture is adjusted too lean, the engine will stop abruptly and might throw the prop, spinner and prop nuts off the front of the engine. Needless to say, this is a very dangerous situation! A little trick to keep the needle valve housing from wearing because of the engine vibration, is to install a small piece of fuel tube on the needle valve

housing towards the base where the needle valve seats. The fuel tube will put just a little tension on the needle valve and will retard the wear of the needle valve housing.

**Low End or Idle Screw:** The low idle needle is on the YS-120SC, YS-140FZ and YS-140L engines. This needle adjusts the low speed mixture setting of the engine. The screw controls air flow at low speed. Rotating the needle into the housing will decrease the air into the engine and increase the flow of fuel or enrich the low speed mixture. Rotating the needle out of the housing will increase the air and decrease the fuel flow or lean the low-speed mixture.

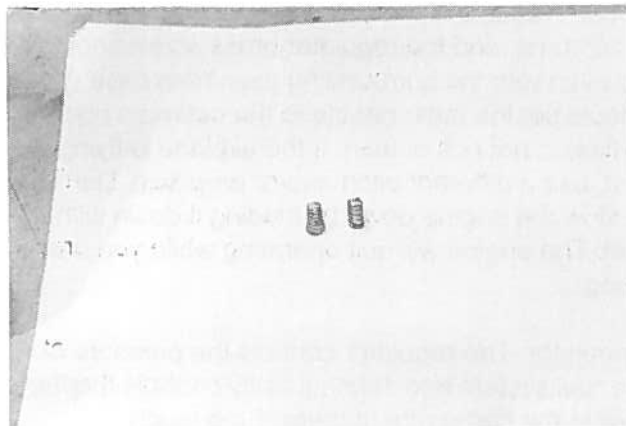
The initial setting of the engine should have the idle screw turned out 1-1/2 turns from gently being bottomed into the seat, the main needle turned out 1-1/2 turns, and the regulator brass screw should be even with the surrounding aluminum case. You should set the main needle to the optimum power setting ... not rich or lean. If the airplane is flying too fast, use a different pitch and/or prop size. Don't try to slow the engine down by loading it down with fuel. The engine will quit operating while you are flying.

**Regulator:** The regulator controls the pressure of the fuel system and subsequently controls the fuel flow to the carburetor. If there is too much pressure, too much fuel will be delivered to the carburetor and the engine will run rich (will slow down while idling and then stop). Too little pressure and the engine will run lean (will speed up while idling and then stop). If the brass regulator screw is rotated out of the housing, the pressure in the system increases. The pressure decreases if the screw is rotated into the housing. The top of the brass regulator screw should be set even with the edges of the surrounding aluminum housing for the initial setting. According to YS, the regulator should not be adjusted from the factory setting on any of the engines.

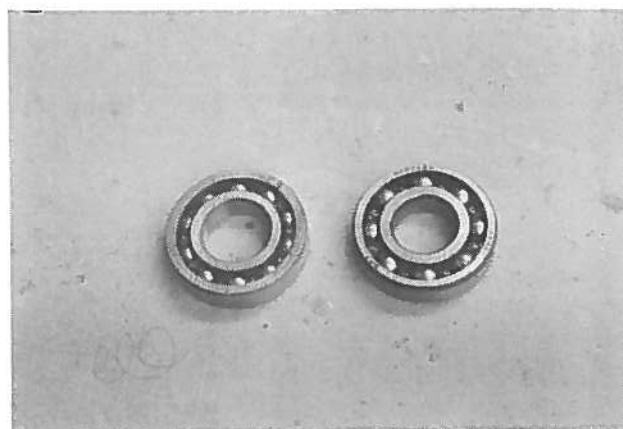
The regulator is extremely responsive to small rotations of the brass cap. The screw should only be rotated in 1/8th turn increments to adjust the fuel flow. The engine should be idling to properly

adjust the regulator. Listen to it; if after idling for a period of time, the engine rpm's begins to increase and then possibly quits, then the regulator is set too lean. If the engine idles and then the rpm's drop off and possibly the engine quits, then the regulator setting is too rich. Remember; adjust the regulator screw 1/8th turn at a time. Any more and you will be chasing the setting forever. Just be patient, work with and get to know the engine; it will be to your advantage. The regulator gasket should be installed onto the regulator that has been completely cleaned of fuel. Also, a regulator gasket should only be used once. Don't reuse regulator or backplate gaskets.

Air Box: After new gaskets have been installed in the air box, the four perimeter bolts should be checked for torque. Tighten them if they are loose.



Regulator Springs: Typical Tapered Spring On The Left, Straight Sided Spring On The Right (This Spring Is Very Responsive To Minor Regulator Adjustments.)



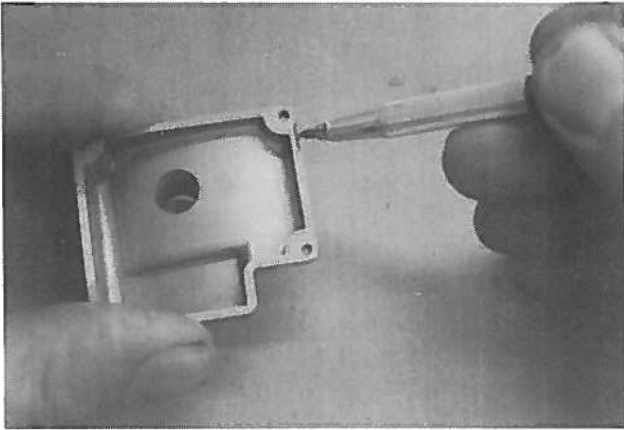
Two Types Of Main Bearings Used In YS Engines. Nine Ball Bearing On The Left, Eight Ball Bearing On The Right. Verify The Correct Bearing For Your Engine



Checking The Main Bearing For Excessive Clearance



Needle Valve Housing with Fuel Tube at the Base



Check Airbox Mating Surface For Excess Material

## TROUBLESHOOTING

## Common Problems With the Engine

PROBLEM	CAUSE	SOLUTION
Engine Won't Run Or Quits	Out of Fuel	Check to ensure there is fuel in the system. If not, refuel the airplane.
	Glow Plug Defective	Check the glow plug with a glow driver. If the glow plug doesn't glow red, replace the glow plug.
	No Pressure In System	Inspect Check Valve: Remove from system and blow and suck on one end of the valve. If air flows both directions, the check valve needs to be disassembled and cleaned. Inspect the silicone diaphragm to ensure there are no holes or tears present.
	No Fuel Flows To The Engine	Check the Fuel system: Disconnect the fuel lines from the check valve connection and the fuel filter. With the fuel tank full, <i>blow</i> into the return line. Fuel should flow out the fuel inlet line to the engine. If there is resistance when air pressure is applied, inspect the fuel tank and lines for pinches or leaks (including the fuel line from the clunk to the fuel tank stopper). Next, draw fuel out of the tank until there is just enough for the fuel tank clunk to be covered. <i>Blow</i> into the return line. Fuel should flow out the inlet line. If fuel doesn't flow out the inlet line and air does, there is a hole or tear in the fuel line from the clunk to the front of the tank.
	Needle Valve Set Incorrectly	Properly set the main needle valve: see instructions in "Maintenance."

PROBLEM	CAUSE	SOLUTION
Engine Won't Run Or Quits (cont.)	Regulator Clogged	Remove and disassemble the regulator assembly. Inspect and clean all components for foreign material.
	Regulator Incorrectly Set	Properly set the regulator: See instructions in "Maintenance."
	Regulator Diaphragm Swollen	Remove regulator and inspect diaphragm. The diaphragm should exactly fit the impression in the regulator housing. If it is minutely larger than the regulator casting impression, replace the diaphragm.
	Valves Out Of Adjustment	Remove the valve cover and check the clearances of the valves. Proper clearances are .004-.01 mm.
	Fuel Tank Or Fuel Lines Clogged or Pinched	Check the fuel system. See "No Fuel Flows To The Engine, Check The Fuel System," in the above paragraph.
Engine Lacks Power or Main Needle Valve Ineffective	No Compression	If the propeller can be spun with no resistance, check the glow plug to ensure it has been installed properly and tightly. To check for leaks around the base of the glow plug, puddle some fuel around the base. Spin the prop; if bubbles appear, there is a leak and either the glow plug or the cylinder head should be replaced. If there is still no compression and the glow plug is secured properly, it's time to disassemble the engine and determine the problem.
	Main Needle Valve Setting Incorrect	Properly set the main needle valve: see instructions in "Maintenance."
	Regulator Incorrectly Set	Properly set the regulator: see instructions in "Maintenance."

PROBLEM	CAUSE	SOLUTION
Engine Lacks Power or Main Needle Valve Ineffective (cont.)	Main Needle Valve Orifice in The Needle Valve Housing Has Enlarged	After the YS engine has been run for a period of time, engine vibration takes its toll. The main needle valve material is much harder than the needle valve housing material. Engine vibration will cause the needle valve to strike the seat of the orifice of the needle valve housing. As the engine is run, the orifice in the housing enlarges. This allows more fuel into the engine and richens the mixture. Consequently the needle valve is rotated into the housing. The process continues until the main needle is almost completely rotated into the housing. When this happens the engine can't be leaned out and the engine runs rough. The solution is to replace the needle valve and needle valve housing.
Engine Stops Violently When Engine Throttle Is Advanced To Full (and probably throws the prop and spinner, VERY DANGEROUS)	The Fuel System Has Not Been Completely Pressurized	The YS engine fuel delivery system depends upon pressure from the crankcase to properly deliver fuel to the carburetor. After venting the fuel system to the atmosphere, it is important, upon starting the engine, to increase the speed of the engine gradually. This will develop the required pressure to maintain the proper fuel flow to the carburetor. If the engine speed is advanced too quickly the engine will not have sufficient fuel flow and subsequently can run extremely lean, possibly causing backfiring and potential damage to the engine.

PROBLEM	CAUSE	SOLUTION
Engine Stops Violently When Engine Throttle Is Advanced To Full (and probably throws the prop and spinner, VERY DANGEROUS)	Main Needle Valve Incorrectly Set. Mixture is too Lean	Properly set the main needle valve: see instructions in "Maintenance."
Engine Stops Violently In Flight (and probably throws the prop and spinner)	Valves Out Of Adjustment	Remove the valve cover and check the clearance of the valves. Proper clearance is .004-.01 mm.

#### UNIQUE PROBLEMS WITH THE ENGINE

PROBLEM	CAUSE	SOLUTION
Engine Runs Rough, Heats Up and/or Quits after it has been dis-assembled, cleaned and re-assembled	Connecting Rod Installed Incorrectly	If the engine starts, then quits after the throttle has been opened and is hot, the connecting rod may be installed incorrectly. Check the crankshaft end of the connecting rod to ensure the bevel of the brass bushing is mating next to the crankshaft counterweight.
	Wrong Main Bearing (This will only apply to the later model "SF" engine)	There are two types of main bearings for the "SF" engine: the eight ball and nine ball bearing. The nine ball bearing is used in the earlier model "SF" engines with 17 mm crankshaft journals. The eight ball bearing is used in all the other models with 15 mm crankshaft journals. Both bearings will fit into any engine case. If a 17 mm crankshaft journal bearing is installed on a later model 15 mm crankshaft, there will be a two mm gap. The engine will appear to spin without problems during assembly. However, shortly after starting, the engine will quit. The remedy is to dis-assemble the engine, place the bearing over the crankshaft journal, if the bearing fits loose, replace it with a 15 mm or eight ball bearing.

PROBLEM	CAUSE	SOLUTION
Engine Runs Rough, Heats Up and/or Quits after it has been disassembled, cleaned and reassembled (cont.)	Regulator Installed Backwards	Check the installation of the regulator case. There is a casting piece on the regulator case. This casting piece should be positioned towards the front of the engine.
	Regulator Plunger Stuck	Remove the brass screw from the regulator. Gently remove the rubber plug valve with a pair of forceps. Inspect the seat for foreign debris. If you see any foreign matter, remove it. Reassemble the regulator.
	Teflon Connecting Rod Retainers Not Installed	If this happens, you are in for a big repair expense! Without the Teflon retainers, the connecting rod will work its way out to the piston sleeve and do a wonderful job of gouging the sides. When you disassemble the engine this will become evident.
	Needle Valve Not Set Correctly	Properly set the main needle valve. See instructions on how to set the main needle valve in "Maintenance."
	Regulator Not Set Correctly	Properly set the regulator. See instructions on how to set the regulator in "Maintenance."
	Backplate/Rotary Valve Clearance Not Set Properly	If the engine starts, then after running it up to full speed, abruptly stops, the clearance between the backplate/rotary valve might be incorrect. This generally happens after the engine has been disassembled, cleaned and reassembled. If you disassembled and assembled the rotary valve and the engine exhibits these symptoms, disassemble the engine and closely examine the rotary valve. If it is stiff to rotate after you have disassembled the engine, disassemble the rotary valve and readjust it again.

PROBLEM	CAUSE	SOLUTION
Engine Won't Run Properly When It Is Brand New	Incorrect Regulator Spring	The factory distributed engines with different regulator springs (refer to the photo in the regulator installation section). The proper spring is tapered. The different spring is cylindrical in shape. If your spring is cylindrical, replace it with a tapered spring.
	Leaking Gaskets	Check all bolts throughout the engine. If all the bolts are tight and the engine continues to run lean, replace the gaskets.
	Leaking Air Box Gasket	Sometimes the surfaces that are bolted together on the air box are warped or were not cast correctly. Check the mating surfaces against a very flat surface. If there is a warp or uneven surface, you have two options: return the engine to the factory or sand the surfaces flat. If you choose to sand the surfaces, place a piece of 600 grit wet/dry sandpaper on a very flat surface. Move the surfaces across the sandpaper slowly and carefully. Work slowly and check the flatness of the surface frequently. After the surfaces are flat, install proper gaskets
	Improperly Tightened Bolts	Check all bolts throughout the engine. Tighten them accordingly.

## Chapter 12 TYPHOON 2+2

### GENERAL

The Typhoon 2+2 is a state-of-the-art pattern airplane. It can be scratch-built with balsa wood. Conventional fiberglass and foam components are also available and can be used. However, the scratch-built, all-balsa airplane is very strong, lightweight and relatively easy to construct. We chose to construct the all-balsa model as an example of another media in which to build a pattern airplane.

A fuselage jig is a must for the all-balsa fuselage, because you are assured of a straight fuselage. The cost is minimal and the benefits are great. Invest in one. We used an Adjust-O-Jig. Gator RC also offers a very good fuselage jig.

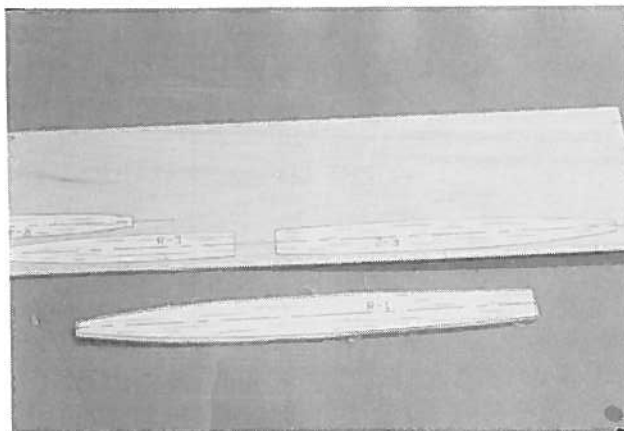
The wings are built over the plans, which you place on a pin board. The plans show a simple wing jig built from balsa wood. Build the wing jig shown on the plans. On our first attempt with the wings, we tried the Adjust-O-Jig. We built one wing panel with the Adjust-O-Jig and the other with the jig shown on the plans. Both panels were constructed straight. However, the Adjust-O-Jig took at least twice as long to construct. We strongly advise using the simple jig shown on the plans. While you are building the jig, build both a left and right, which will allow you to construct the wing panels so the bottom sheeting is on each panel at the midpoint of wing construction. This helps with the alignment process. The construction and alignment will be explained later in the building process.

### COMPONENT PREPARATION

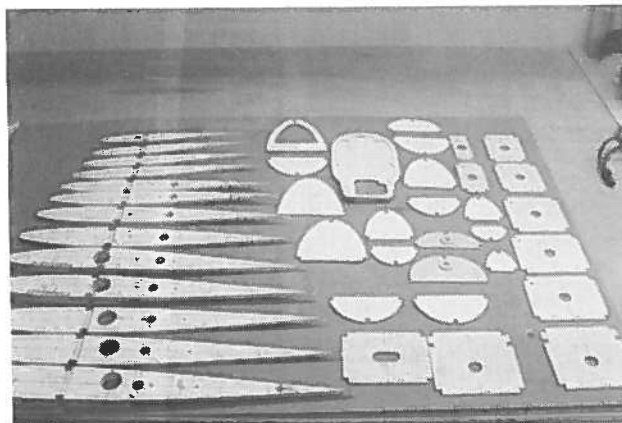
We found that cutting all formers and ribs first before beginning construction helped organize the building process.

**12.1.** Cut all the formers and wing ribs from the plans. Draw centerlines on the balsa sheets for the

formers, wing ribs and firewall. Using a glue stick, paste the paper templates onto the appropriate thickness of balsa wood, aligning them over the centerlines on the balsa or plywood sheets (when you remove the paper template you will have a centerline on each former in the proper location). Cut and sand all fuselage formers (bottom, middle and top), ribs and the firewall. Drill a 1/2" diameter hole through each main former for servo wires. Drill a 3/16" diameter hole for the antenna wire housing. These holes are not shown on the plans, but will be very helpful when you install the radio system.



Ribs And Formers Pasted To And Then Cut From Balsa Stock



All Ribs And Formers Cut From Balsa Sheets

## VERTICAL STAB CONSTRUCTION

As with any pattern airplane, we start construction with the vertical stab. If you make a mistake on this component, you can throw it away, start over and you haven't lost much. If you need more help constructing the vertical stab, refer to the wing construction section for photos showing each step. The wing, vertical and horizontal stabs follow the same basic construction steps.

**12.2.** Tape the vertical stab plan down onto a pin board. Tape waxed paper over the stab plan. The waxed paper prevents the balsa components from becoming bonded to the plan.

**12.3.** Temporarily pin a piece of 1/2"x1/4" balsa over the location of the leading edge on the plans. Transfer the locations of the stab ribs onto the balsa. Follow the same procedure for the trailing edge. Once marked, remove the leading and trailing edges from the plans.

**12.4.** Pin a piece of 1/4"x3/4" balsa over the leading edge on the plans. Also, pin a piece of 1/4"x1/4" balsa over the trailing edge of the plans. These pieces are used to elevate the leading and trailing edges over the plans so the ribs don't touch the plans.

**12.5.** Place the leading edge balsa piece on top of the 1/2"x3/4" piece already pinned to the pin board. Align the marks on the leading edge with the ribs shown on the plans. Once aligned, pin in place. Place the trailing edge balsa piece on top of the 1/4"x1/4" balsa piece already pinned to the pin board. Align the marks on the trailing edge with the ribs shown on the plans. Once aligned, pin in place. Allow enough length on the ends of both leading and trailing edges to extend past the endpoints as indicated on the plan. You will cut off the excess later.

**12.6.** Place the stab ribs, in their proper locations, between the leading edge and the trailing edge. It will be necessary to sand the proper angle on the tip of the ribs to fit into their proper locations.

**12.7.** Using a drafting or builder's square, adjust the ribs so they are all square to the building surface. The friction of all the balsa pieces should hold everything together while you perform this step. If not, use pins. Once you have checked and double-checked that all the ribs are square, glue them in place. Use a glue of your choice. We use CA but if you have allergic reactions to it, try Duco.

**12.8.** Install the 1/16" strips between the ribs as indicated on the plans.

**12.9.** Install the vertical stab sheeting (to prepare the sheeting, see the chapter on foam core wing construction). Before installing the stab sheeting, mark the location of the ribs on the sheeting by drawing light lines with a felt tip marker. This will help you pin the sheeting to the ribs. Using an epoxy brush, paint slow cure epoxy on the top of all the ribs. Use lots of pins to hold the sheeting in place. Once you think you have all the pins inserted, press gently against the sheeting between the pins and listen to hear, and feel, if the sheeting rebounds off the rib. If it sounds and feels solid, you're okay. If it rebounds, insert more pins. Ensure that all the surfaces are mated properly.

**12.10.** Once the epoxy has cured, remove the pins. Remove the vertical stab from the building board. Turn it over and pin it down to the pin board. Check to make sure all the components are square and level and glue the other piece of sheeting onto the structure. Use the same pinning technique as stated previously. Once the epoxy has cured, remove the pins, remove the vertical stab from the pin board and shape it with sand paper.

**12.11.** Construct the top vertical stab tip. This appendage receives a lot of unintentional abuse. While swinging the fuselage around during the construction of the fuselage, it is constantly exposed. If you fabricate it out of only balsa wood, we can almost guarantee it will break off. We incorporate 1/32" plywood into its construction.

Trace the elevation outline of the tip onto 1/32" plywood. Once cut and sanded, glue it to 1/2"

balsa stock. Trim the balsa to the configuration of the plywood. Glue another piece of 1/2" balsa stock to the other side of the plywood, forming a sandwich of balsa-plywood-balsa. Trace the outline of the airfoil of the tip onto 1/32" plywood. Once cut and sanded, center the piece on the bottom of the already-constructed sandwich tip. Now you have plywood on the bottom of the tip that matches the airfoil and plywood in the center that matches the profile of the tip. This construction will result in a very strong vertical stab tip that will withstand minor abuse and not break off the airplane. Check the centerlines of the vertical stab and the tip and glue the two together. Sand the tip to the configuration as noted on the plans.

## FUSELAGE SIDES AND BOTTOM

The fuselage is a long balsa box with a turtleneck on the top and bottom. After studying the plans and keeping the long balsa box concept in mind, the construction process becomes very simple. However, we found that there are a few tricks to ensure a straight fuselage. We will explain the tricks in detail as we proceed. We thought we would highlight some of them in advance.

We have yet to find a perfectly straight piece of balsa wood. If you try to splice two curved pieces of 3" balsa together, you end up with two curved sides to your fuselage. More than likely this will cause final alignment problems. Instead, we start with two curved pieces of 4" balsa, splice them together, determine the centerline, determine the proper width and remove the excess. Voila ... straight fuselage sides from curved balsa pieces.

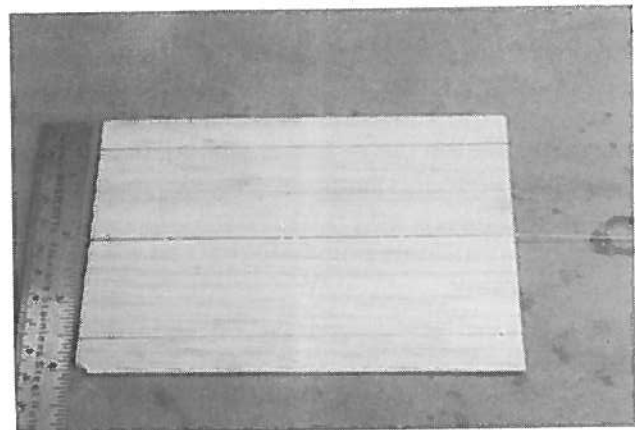
We build the main box and bottom of the fuselage before removing it from the jig. Inserting and removing the fuselage from the jig could lead to a misalignment. We finish the fuselage top after the wings and stab halves have been fitted and aligned to the fuselage sides. We want access to the back wing adjusters during the wing alignment process, without having the top of the fuselage obstructing access.

**12.12.** Locate the centerlines of the engine mount on the firewall. As per the plans, glue the appropriate backing material to the back of the firewall. At the location of the motor mount bolts, install plywood. Install 1/8" balsa in all other areas. Drill holes for the motor mount bolts and install the appropriate-sized blind nuts. Locate and drill the holes for fuel tubing and the throttle control cable. Align the plywood former for the cowl on the firewall. Using the cowl former as a template, drill matching holes through the firewall and install 4-40 blind nuts in the back of the firewall. You should now have the following items incorporated into the firewall:

- Motor mount bolt holes and blind nuts;
- Cowl former holes and blind nuts;
- Fuel line holes; and the
- Throttle cable hole.

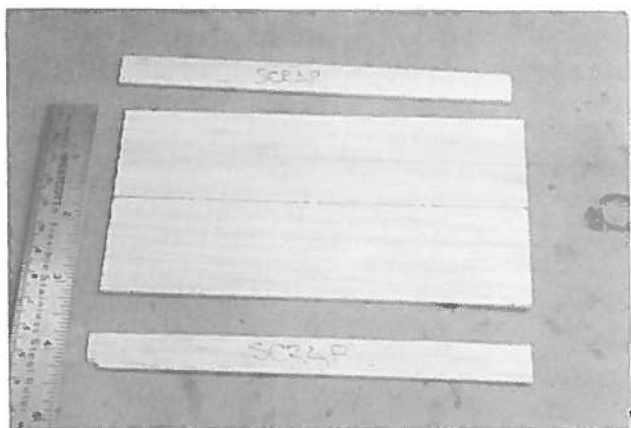
**12.13.** Begin constructing the sides of the fuselage. Using 1/8"x4"x36" balsa sheets, splice the two-piece sides of the fuselage together. Locate the splice as per the plans.

**12.14.** At each end of the fuselage sides mark the centerline of the 4" sheet. Pull a piece of string taught between the two centerline marks at each end of the fuselage sides. Mark the location of the string on each side with dots, using a felt tip pen. Connect the centerline dots using a straight edge and felt tip marker.



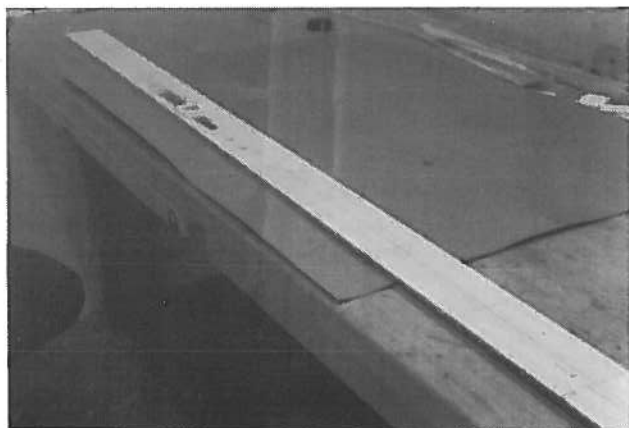
Establish the Centerline on the Four Inch Fuselage Sides

**12.15** From the centerline measure 1-1/2" on each side. Connect these outside marks with a straight edge and a felt tip marker. Cut off the excess from the sides of the fuselage. Note: We took the liberty of using a much shorter piece of balsa than the length of the fuselage for demonstration purposes.

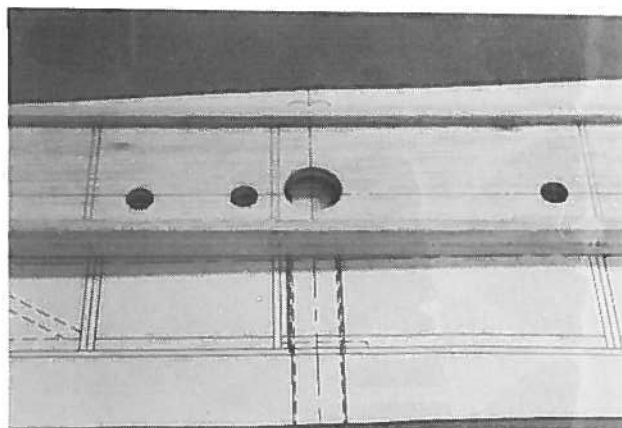


Center Established w/ String, Width Established From CL

**12.16.** Temporarily tack glue the two sides together. Tape the two adjoining fuselage sides to the plans. Transfer the locations of all the formers from the plans to one side of the fuselage using a carpenter's square and a fine felt tip marker. Using a carpenter's square, transfer the marks from one fuselage side to the other.



Tack Glue The Fuselage Sides Together



Transferring Marks From The Plans To The Fuselage Sides

**12.17.** Study the plans at the firewall. Notice the right and down thrust designed into the airplane. *Do this by making the left side of the fuselage a fraction of an inch longer and the right side a fraction of an inch shorter.* Also, the firewall is not perpendicular to the centerline of the fuselage. When you transfer the marks from the plans to the balsa, keep these two features paramount in mind. If you don't incorporate the down and right thrust into the airplane, it will be difficult to trim the airplane.

**12.18.** Locate the wing and stab tube centerlines, wing and stab incidence adjusters, aileron and elevator servo wire holes on the fuselage.

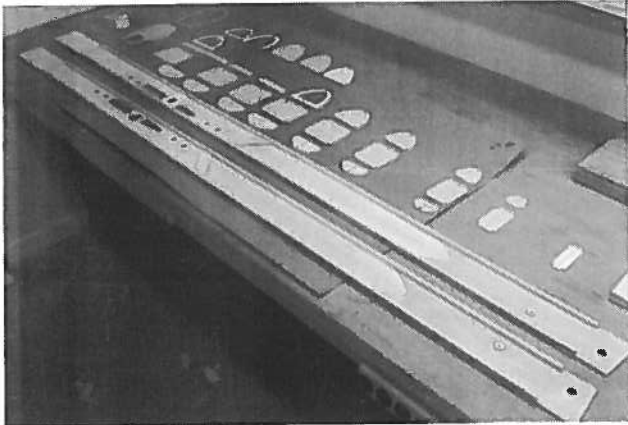
**12.19.** Drill or cut holes through the sides of the fuselage for the wing and stab tubes, wing and stab incidence adjusters and aileron and elevator servo wires.

**12.20.** Glue the 1/4"x1/4" longerons onto the inside of the fuselage sides.

**12.21.** Glue the splice backup plates onto the fuselage sides.

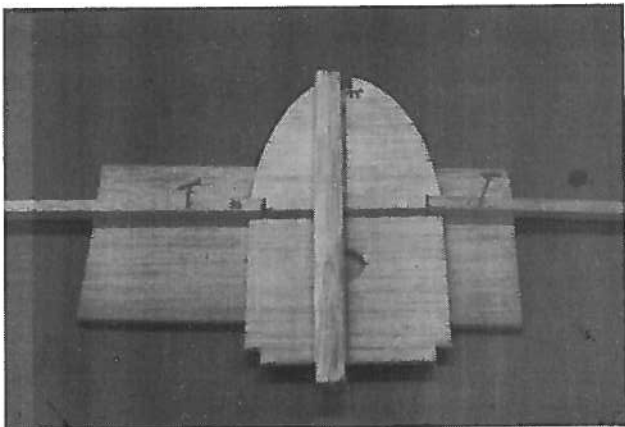
**12.22.** Cut lite-ply backup plates for the wing incidence adjusters and wing tube. Lay them in place inside the fuselage (but do not glue them in place). Mark the holes for the incidence adjusters and wing tube on the backup plates.

**12.23.** Separate the two fuselage sides. Lay them on your workbench and place the bulkhead and firewall pieces above the two pieces as shown in the photo. Verify that all pieces have been cut-out and are ready for assembly.



Verifying That All Fuselage Parts Have Been Fabricated

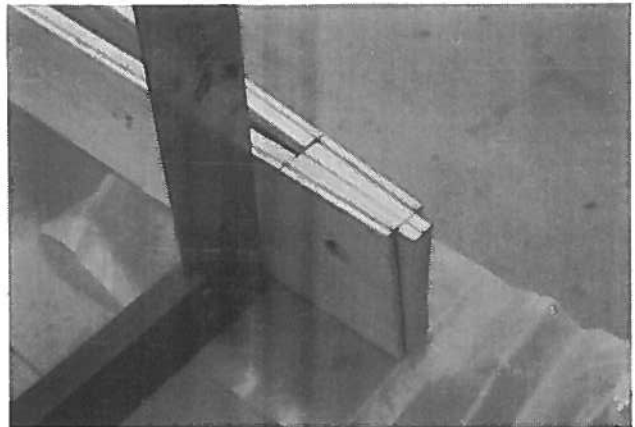
**12.24.** Install the top formers from F3B through F9B to the main formers. Construct a small jig out of scrap balsa to assemble the bottom and main piece of each former. The two 1/4" square pieces are pinned to the scrap balsa to ensure a tight fit around the fuselage longerons. The vertical piece ensures that the centerlines of each piece line up properly. Shave the bottom piece appropriately to ensure the centerlines of the two pieces are aligned properly.



Former Jig To Ensure Each Piece Is Centered Properly

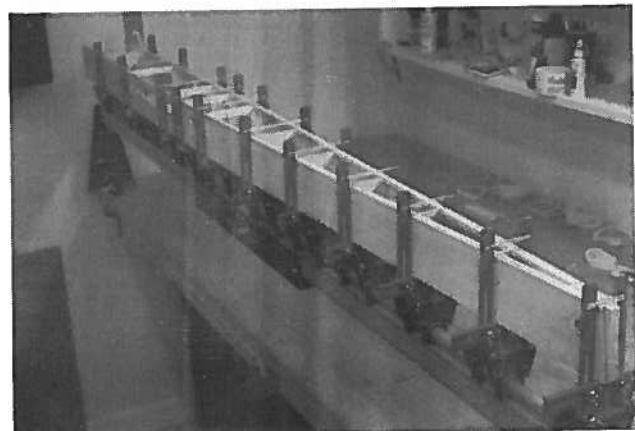
**12.25.** Assemble the back end of the fuselages with the spacer block. Lightly tack glue the front end of the fuselage together. Spread the rear two

sides apart and slide the spacer block in place. Check to ensure the two sides are aligned properly and are square. Clamp the assembly in place and place alignment marks on all three pieces. Take your time. This is the start of building your fuselage straight and true. Once you are satisfied everything is aligned and properly marked, disassemble the pieces, apply epoxy to the components, place them together, align them, clamp them in place, check alignment one more time and then let the epoxy cure.



Rear Assembly Of The Fuselage

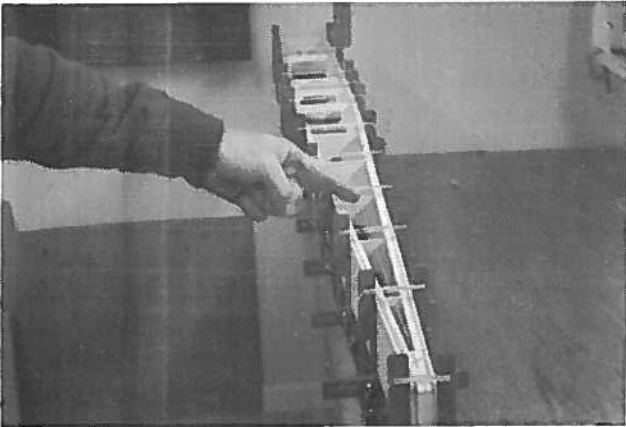
**12.26.** Place the sides and rear assembly of the fuselage upside-down in a fuselage jig. At the same time insert the formers in their appropriate places. Don't glue anything in place yet. Hold everything against the jig members with rubber bands.



Fuselage And Formers Rubber Banded To Fuselage Jig

**12.27.** Loosen the jig stations, align each former centerline over the fuselage jig centerline and then tighten the jig station clamps again. Rubber band the formers in place, but do not glue them yet!

**12.28.** Stretch a string from the very rear center of the fuselage to the firewall centerline mark. Check each former to ensure each is properly centered on the line. If there is a discrepancy between the string centerline and the jig centerline, stop, determine what the problem is, and remedy it. The final alignment and ultimate performance of the airplane depends upon making sure all critical parts are aligned.



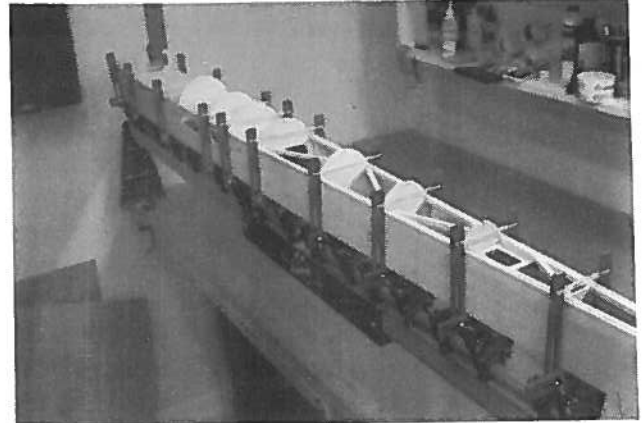
String Strung Tightly Over Centerlines Of Formers

**12.29.** Check and recheck the following

- Location of the formers;
- Centerline alignment of the formers; and the
- Squareness of the fuselage.

When you are sure all the fuselage components are square and aligned, glue the formers in place.

**12.30.** Install the bottom formers from F3B through F9B to the main formers. Make sure the centerlines of the "bottom" formers are properly aligned with the centerlines of the "main" formers. To do this, use a straight edge placed on the centerline of the "main" former. Then align the bottom former centerline to the straight edge. Adjust the bottom former 1/4"x1/4" grooves as necessary for alignment.



Bottom Formers Installed On Main Formers

**12.31.** Install the 1/4"x1/4" longeron through the slots in the bottom of the formers.

**12.32.** Install the 1/8" balsa floor between F2 and F6. Install with the grain oriented perpendicular to the long axis of the airplane as noted on the plans.

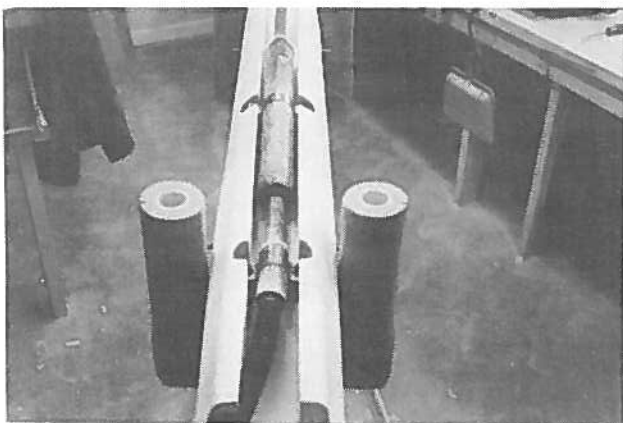
**12.33.** Install the cross-bracing between F6 and F10.

**12.34.** Install the lite-ply floor between F1 and F2.

**12.35.** Install the 1/4" balsa doublers between F1 and F2.

**12.36.** Install the triangular balsa stock between F1 and F2.

**12.37.** This is a good time to install the engine exhaust mounting system. If you install your mounts now, you can "build around them" to ensure proper clearance. Install the engine on the firewall. Fasten the pipe to the exhaust port of the engine. Position your mounts and install the appropriate blind nuts or hardware.



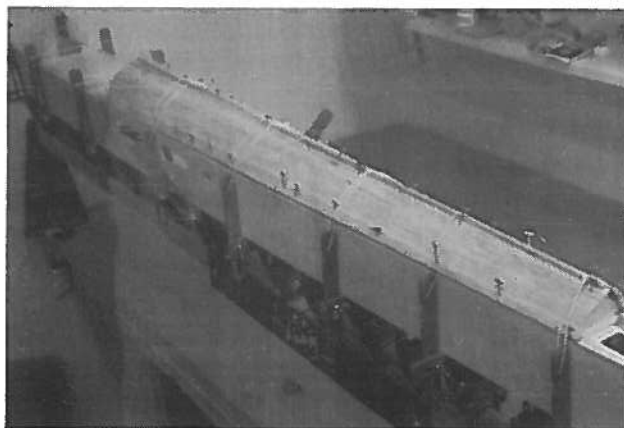
Exhaust System Mounted On Bottom Of Fuselage

**12.38.** Install the 1/4" strip sheeting from former F6B to F10B. Study this carefully before you start. Notice, if you use 1/4" wide strips on the entire length of the sheeting, you will have a big triangular gap at F6B after you cover former F10B. To solve this problem, you're going to have to cut strips of sheeting that vary in width. We used the following approach to solve the problem: measure the length of the edge of former F6B and F10B to be covered with sheeting, with a ruler. Since F6B is the largest of the two distances, divide the distance by 1/4" to determine the number of 1/4" strips you are going to need. For example, If the outside edge of F6B is 10", divide 10" by 1/4" and you get 40. Now, measure former F10B. Take that dimension and divide by 40. This will give you the width of the sheeting at the F10B former. If the outside edge of F10B is 5", divide 5" by 40 and you get 1/8". Therefore, you will need to cut 40 strips 1/4" wide at one end and 1/8" wide at the other. Remember, this is an example, you need to determine the specific lengths and widths for your model.

or

Spray liberally or soak 1/8" sheets of balsa wood in a mixture of one-half/one-half ammonia and water. While damp, place on the formers and form them to the curve of the formers. Once in place use pins and rubber bands to secure in place until the balsa dries. Be patient, drying the balsa is typically an overnight operation. Don't try and rush it by using a

heat gun. It has been our experience that the balsa will shrink crack.



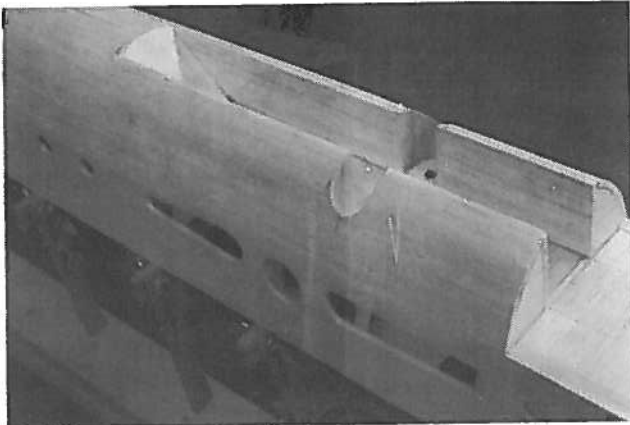
Wetted Balsa Sheets Formed Over The Bottom Formers

**12.39.** Once the balsa is dry, remove the rubber bands. Mark the sides and the middle of the longeron on the sheets and trim off the excess. Dry fit each piece. Once you're satisfied with the fit, glue the pieces in place using either epoxy or slow cure CA glue.



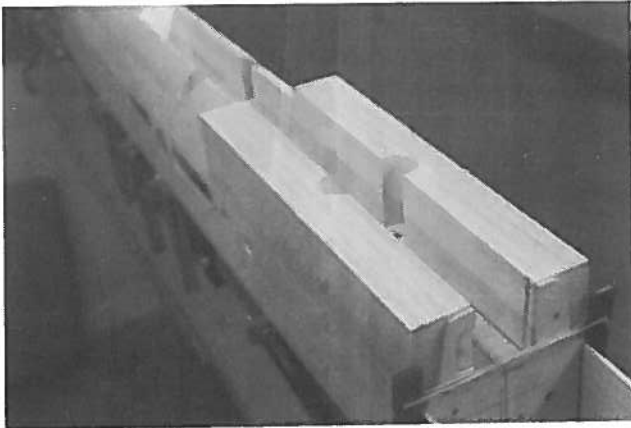
Curved Balsa Sheets Trimmed And Glued In Place

**12.40.** Install the back of the exhaust pipe tunnel.



Exhaust Tunnel Back In Place And Mounting Bolt Recesses Sheeted

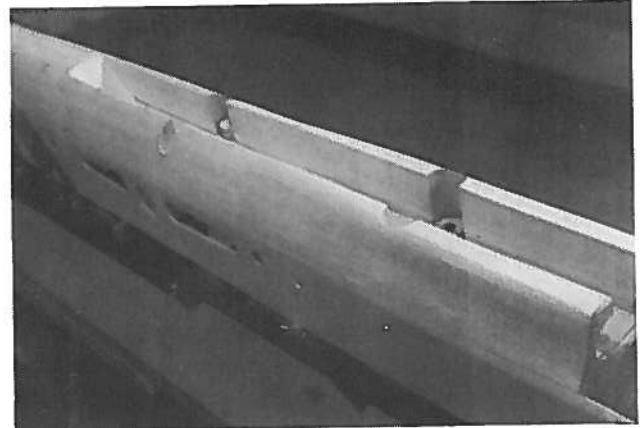
**12.41.** Install the solid balsa blocks between formers F6B and the firewall.



Solid Balsa Blocks Installed Behind The Firewall

**12.42.** Trim the solid blocks and sand them to conform to the curves of the fuselage.

**12.43.** Remove the fuselage from the jig. With the cowl former bolted to the firewall, temporarily install the cowl onto the firewall and rough-shape the bottom of the fuselage.



Solid Blocks Shaped To The Curves Of The Fuselage

**12.44.** Install the solid balsa block on the bottom rear of the fuselage.



Solid Balsa Block On Bottom Rear Of Fuselage

**12.45.** Cut and fit the interior fuselage wing tube to the inside of the fuselage.

**DON'T GLUE THE INTERIOR WING TUBE IN PLACE YET.**

We deviate from the plans when fitting and installing the interior fuselage wing tube. We cut lite-ply rings instead of the rectangular pieces as called for on the plans. Doing this allows us to adjust the interior fuselage wing tube in all directions when fitting the wings to the fuselage.

Now, stop construction of the fuselage until you have the wings and stabs constructed. The wings

and horizontal stab will then be fitted and aligned to the fuselage. Once the alignment is complete, construct the fuselage top.

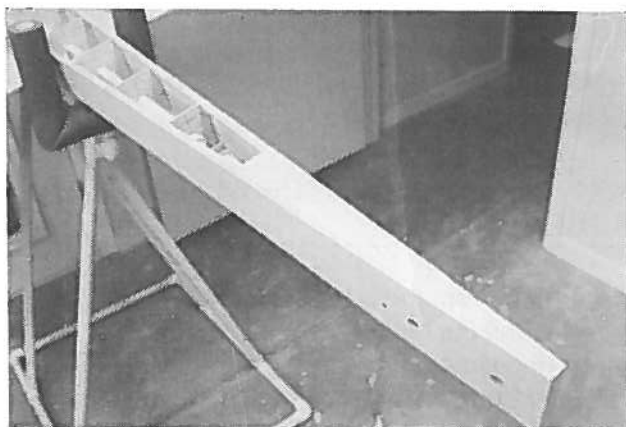
## FUSELAGE TOP

Before starting the fuselage top construction, check the alignment of the wings and vertical and horizontal stabs to the fuselage. Now, we are going to set the incidence of the wing and stab panels.

The incidences are based upon the centerline of the fuselage. If you haven't established the fuselage centerline on the outside of the fuselage sides, now's the time. The wing and horizontal stab incidences are as follows:

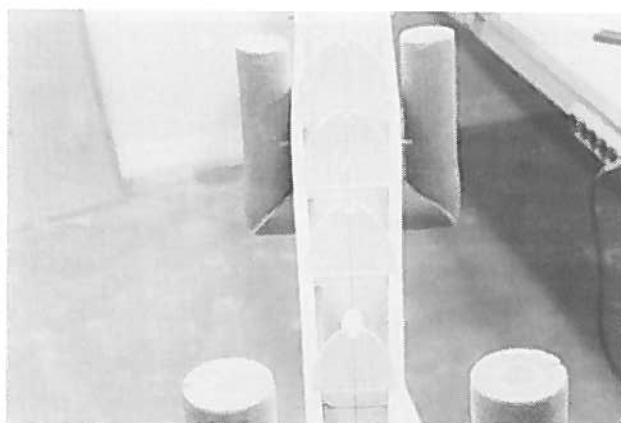
SURFACE	INCIDENCE
Wing	.5° positive incidence
Horizontal Stabs	0° incidence

**12.46.** Complete the fuselage top construction. Install the 1/8" decking from former F10 to the back of the fuselage. Draw a centerline on the top of the decking. This is for the installation of the vertical stab. Make sure you're very accurate. Use string lines, drafting squares, and your eyes. *Use anything you want, but make sure the vertical stab centerline is in line with the centerline of the fuselage.*



Install Decking At Rear Of Fuselage

**12.47.** Install formers F6T to F10T to the top of the main formers.



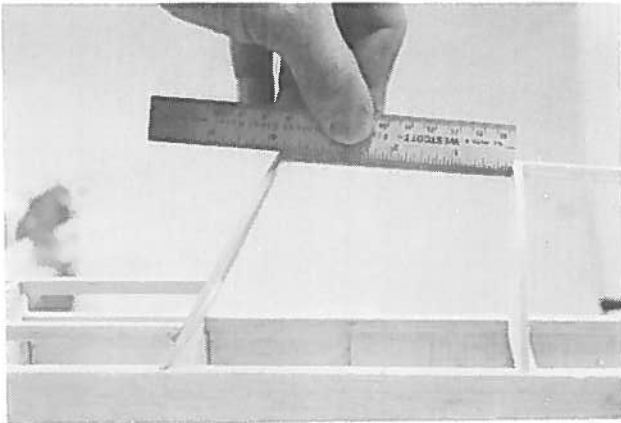
Top Formers Installed

**12.48.** Install the longeron on the top of the formers from F6T to F10T. Extend the longeron past the anticipated location of former F5T.



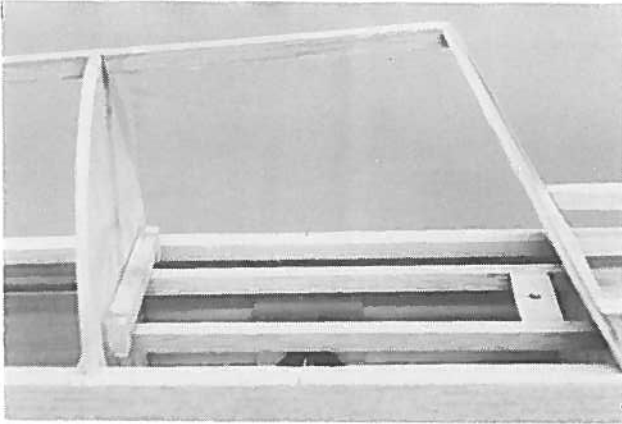
Longeron Installed On Formers

**12.49.** Install Former F5T. Measure, on the plans, the distance from former F6T to the front of former F5T along the longeron. Transfer that measurement to the 1/4"x1/4" balsa longeron. Locate the top of former F5T at that point and glue it in place.

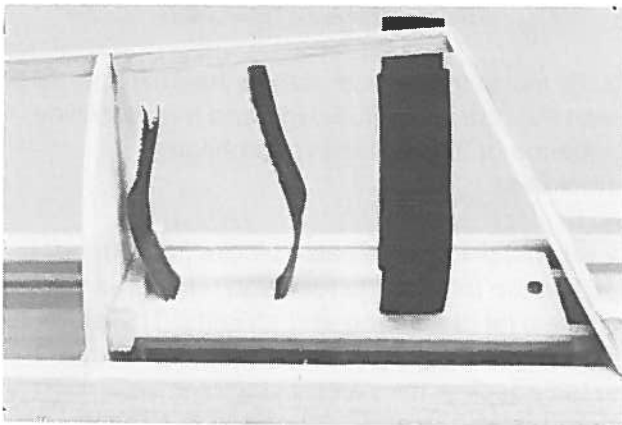


Installing Former F5T

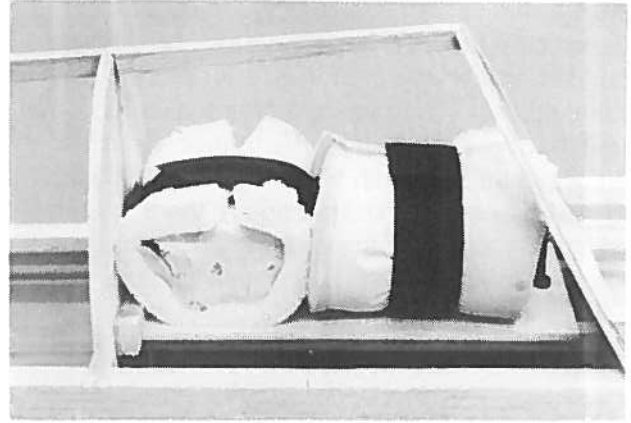
**12.50.** Install the support for the battery and receiver floor behind F5T.



Support For Radio Installed



Platform Installed w/ Velcro Straps



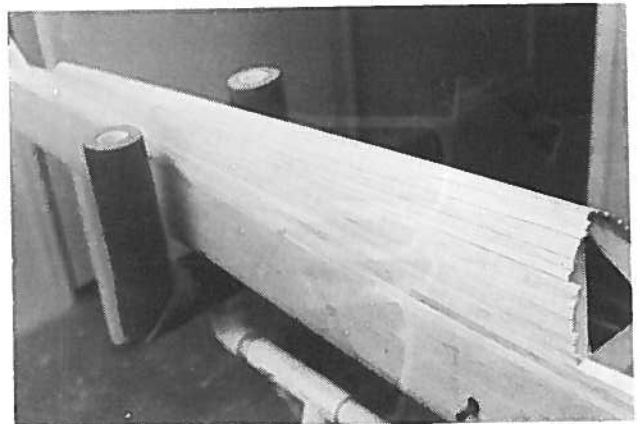
Receiver &amp; Battery Temporarily Installed For Clearance

**12.51.** Sand the bottom of former F5Tf (the small "f" denotes the front portion of the rear former of the canopy) at an angle to match the back, bottom of the canopy. Position former F5Tf in front of former F5Tb (the small "b" denotes the back portion of the rear former of the canopy) and tack glue in place.

**12.52.** Sand the two formers so they are identical. Doing this ensures that the decking on the fuselage matches the decking on the canopy.

**12.53.** Set former F5Tf to the side for the canopy construction.

**12.54.** Sheet the turtledeck with 1/4" balsa planking. See the planking instructions in the fuselage section on how to measure, cut and install the planking.



Turtledeck Sheeted w/ Planking

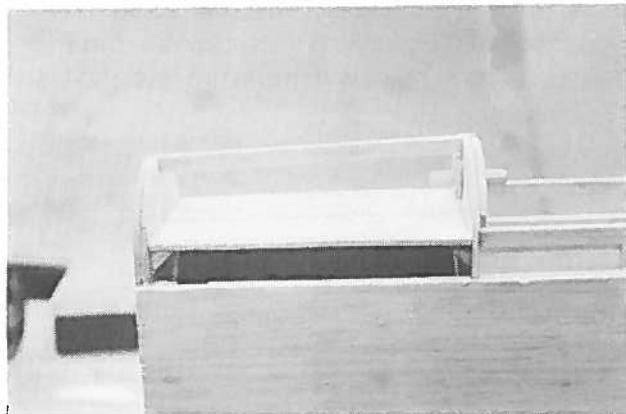
Here's a little secret! Notice how the decking extends past the last formers. Leave the decking extended and shape the turtledeck before cutting off the excess. When you cut off the excess, leave about 1/16" extending past the former. Gently sand the excess off flush with the former. If you do this, you will have a crisp, sharp edge at the end of the decking. If you cut off the decking and then sand it, you will round the edge. This doesn't look as nice on the finished model.



Decking Extended Past Former And Shaped

**12.55.** Install the top formers from F2T through F4T.

**12.56.** Install the lite-ply reinforcing piece between formers F1T and F2T.



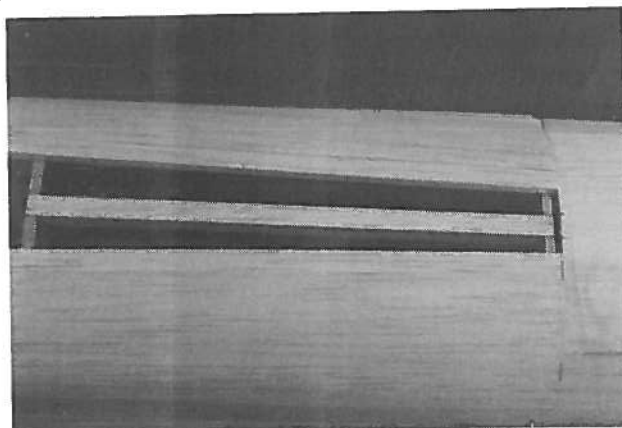
Former, Lite-ply And Longeron Installed

**12.57.** Install the longeron between Formers F2T and F4T.



Longeron Installed

**12.58.** Sheet the turtledeck with 1/4" balsa planking between formers F1T and F2T. Follow the same procedure explained for the bottom turtledeck.

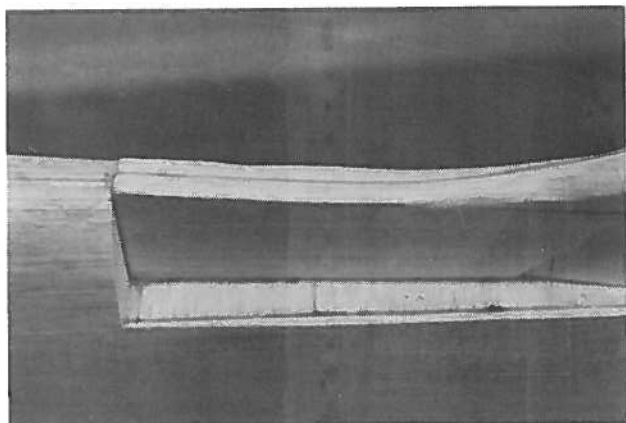


Space Between Sheeting To Be Custom Cut

**12.59.** Install the vertical stab to the fuselage. Align it with the rear of the fuselage and the centerline on the top of the decking you previously established.

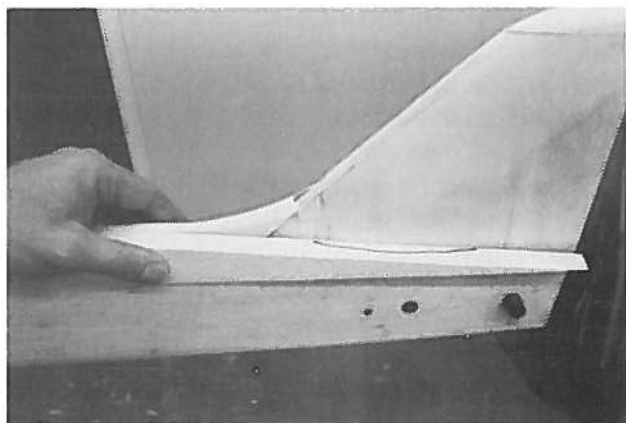
**12.60.** Install the solid balsa blocks from former F10T to the back of the fuselage. This area will receive a lot of sanding and shaping. Therefore, to maintain the integrity of the curved transition from the turtledeck to the vertical stabilizer, we incorporate a piece of 1/32" plywood into the assembly. The plywood is harder to sand, consequently you increase your chances of not losing the transition curve. Trace the outline of the filler piece between the turtledeck and the vertical

stab on a piece of 1/32" plywood. Cut out and glue the 1/32" plywood to 1/4" balsa. The balsa should be a little larger than the plywood piece. Trim the balsa to the shape of the plywood. Glue another piece of 1/4" balsa to the other side of the plywood piece. Install this component in place.



Transition Piece Between Turtledeck and Vertical Stab

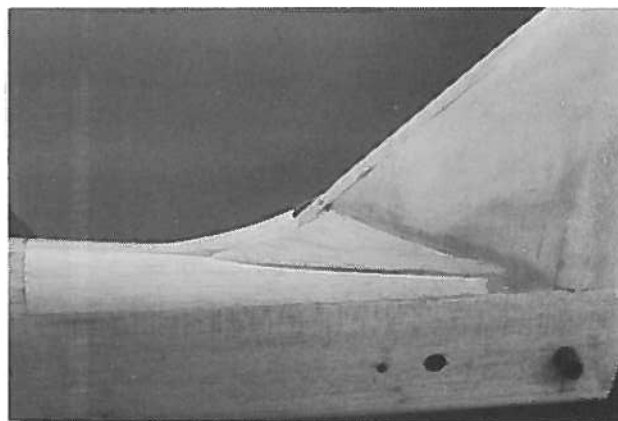
**12.61.** Fill in the areas on each side of the transition piece with soft balsa. Sand to the required contour. For the final touch, fill in the area with an epoxy filler or lightweight body putty. Once cured, finish sand to a smooth contour.



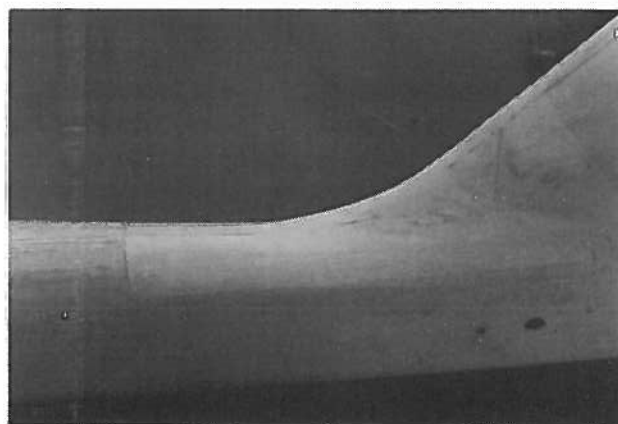
Side Balsa Filler Pieces Being Fitted



Side Balsa Filler Pieces Installed



Additional Balsa Filler Piece Installed



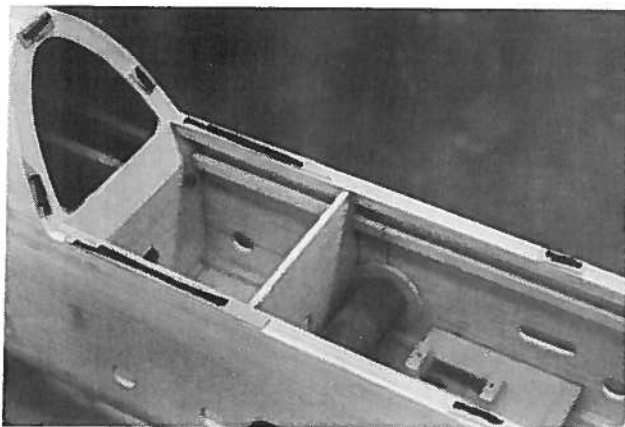
Transition Area Filled and Sanded Smooth

Fuselage is now complete.

## CANOPY CONSTRUCTION

We build the canopy after the fuselage is complete. This way we can cut and sand it to the exact contour as the surrounding fuselage area. You can let your imagination run wild with the clear canopy. You can build up a finished cockpit area with a pilot or you can leave it void and view the internal components of the fuselage. Whatever you do will be right; there is no wrong way to finish the cockpit. You have options on how to finish the canopy: it can be left clear, tinted with conventional dyes, or painted. Again, this is an area of individuality; how you finish it is up to you. Look ahead when constructing the canopy to plan your end result. However, the following covers the basic canopy frame construction.

**12.62.** Place 1/64" to 1/32" (depending upon your finish materials) scrap wood pieces on the front and back formers and the side longerons in the canopy area. This will give you the proper clearance between the canopy and the fuselage for the finish materials.

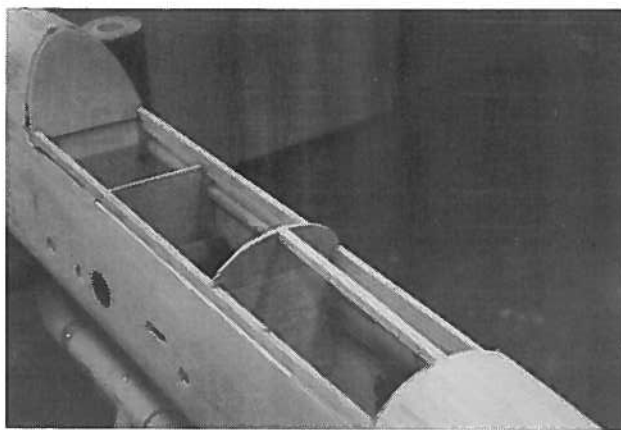


Spacers For Finish Material Clearance

**12.63.** Locate formers F5f (the rear canopy former) and F2b (the front canopy former) in their proper positions. Don't glue them to their matching formers, F5b and F2f (these are the corresponding fuselage formers). Just pin them in place.

**12.64.** Pin the 1/4"x1/4" longeron to the top of the fuselage longeron between formers F2T, F3T and

F5T. Once satisfied with the fit, glue the longerons to the formers.



Canopy Formers and Longerons Installed

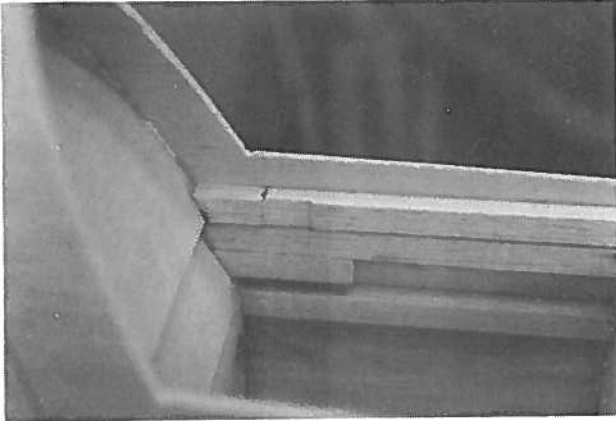
**12.65.** Sheet the formers between F2T and F5T with 1/8" balsa. Cut the sheeting for the sides of the canopy from a balsa sheet. Follow the outline as shown on the plans. Glue it in place. Finish the sheeting in front of the cockpit area.

**12.66.** Sand the sheeting to match the adjacent fuselage parts.

**12.67.** We used a different method to secure the canopy to the fuselage than what's shown on the plans. We didn't like the idea of having holes in the top of the canopy, which allows debris to accumulate on the inside. The canopy gets scuffed up (by sticking a screwdriver or ball driver into them to either install or remove the canopy). Holes in the canopy also distract from the beauty of the airplane lines. We came up with gluing tabs to the canopy that protrude down into the fuselage. The tabs are used to align and anchor the canopy to the fuselage. The only revealing sign of anchors are two holes in the side of the fuselage towards the rear of the canopy.

**12.68.** Locate the spot you wish to fasten four short Popsicle sticks that will extend from the canopy longeron down along the side of the fuselage. Ours are about 1-1/4" from the back of the canopy. Trim the longerons in this area on either the fuselage or the canopy so they are even with each other. Install a piece of 1/4"x1/4"x1"

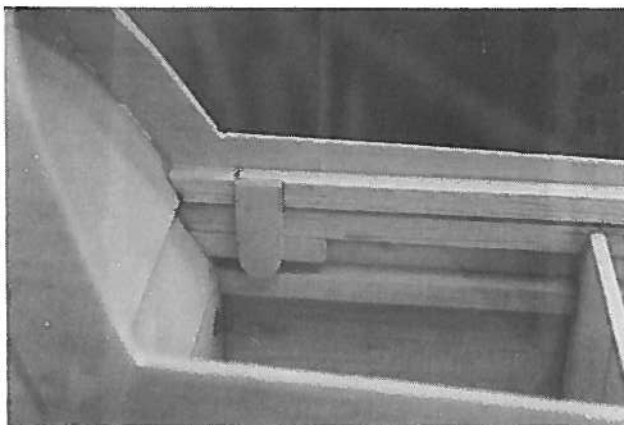
hardwood under the fuselage longeron and against the fuselage. This will be the backing for the 4-40 bolt that will secure the canopy.



Longerons trimmed flush w/ each other and hardwood stock installed

**12.69.** Drill a 3/32" hole on the outside of the fuselage, opposite and centered on the hardwood stick. Drill the hole through the fuselage side and through the hardwood stock. On the outside of the fuselage, using a brass tube a little larger than the diameter of the head of a 4-40 bolt, cut a hole through the balsa sides down to the hardwood backing material.

**12.70.** Cut two pieces of Popsicle stick about 3/4" long. Glue them to the longeron on the side of the canopy. Make sure this stick is long enough to extend past the hole in the fuselage.



Popsicle or stir stick installed

**12.71.** Reinforce the Popsicle stick/longeron attachment point. We installed a "floor" in the

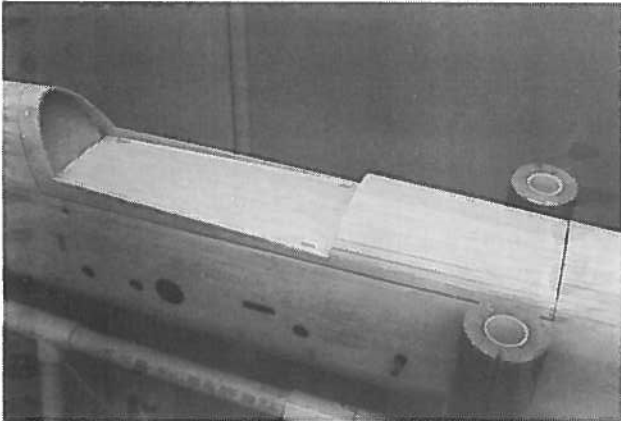
canopy area and reinforced the attachment point using scrap stock glued to the Popsicle stick and the floor. If you leave this area open, you will have to devise a reinforcement system of your own.

**12.72.** As a guide and side support, install another set of Popsicle sticks about 1/3 to 1/2 of the distance from the front of the canopy. Use the same installation technique as noted above, except *don't* drill the holes in the sides of the fuselage.

**12.73.** We realize that this step is out of sequence, but we knew you would be wondering how the canopy was going to stay attached to the fuselage. So we're including this step now rather than later. After the canopy and fuselage are completely finished, install the canopy on the fuselage. Insert a 3/32" drill bit into the hole in the fuselage and drill through the Popsicle stick. Remove the canopy, enlarge the hole in the Popsicle stick to accommodate a 4-40 blind nut and install the nut.

**12.74.** Install the 1/8" balsa floor between formers F3T and F5T. Again, the floor we show is an option. It is up to you what you do with the area between the canopy and the fuselage. Use your imagination, install a pilot, detail the cockpit, or leave it open. Remember, the airplane uses a clear canopy so this area will be visible when the airplane is finished. We recommend at least a floor, since the floor acts also as a stiffener for the canopy assembly.

**12.75.** The canopy is now complete.

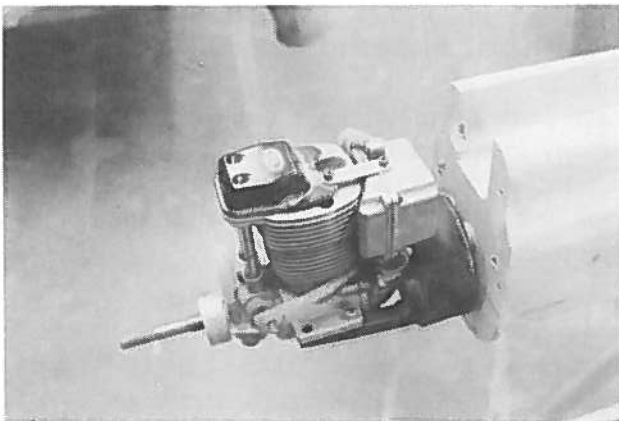


Canopy Complete W/ "Floor" and Sheeting

## ENGINE COWL INSTALLATION

The engine cowl is fairly straightforward. The only task we wish to caution you in advance about is fitting the cowl to the fuselage. *Go slowly!* Sand a little, fit; sand a little, fit. It will pay to go slowly and make sure the fit is correct.

**12.76.** Install the engine on the fuselage.



Engine Installed On Fuselage

**12.77.** Trial-fit the engine cowl onto the front of the fuselage. Note how much material needs to be removed from the back of the cowl. You want the cowl to fit tightly against the fuselage and have a 1/16" gap between the spinner backplate and the cowl front ring. Remove the cowl and remove the excess fiberglass, except for a 1/4" band. Again, trial fit the cowl to the front of the fuselage and again note how much material you need to

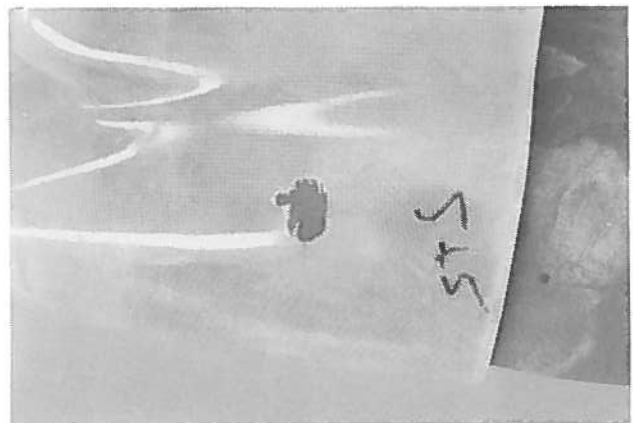
remove. Slowly remove material until you have the required fit between the fuselage and the spinner backplate.

**12.78.** Install the cowl former to the firewall using 4-40 bolts.

**12.79.** Install the cowl over the cowl former. If you cut the cowl former to the size noted on the plans, it will be slightly larger and the cowl won't fit. However, try to fit the cowl and note the spots where the cowl extends past the side of the fuselage. Remove the cowl and cowl former and sand a small amount of material off the cowl former at the high spots noted. *Go slowly!* The difference between a tight fit and a sloppy, loose fit is very little.

**12.80.** Install the cowl over the engine. Note where to remove fiberglass to accommodate the engine. Remove the cowl and then remove excess fiberglass material. Continue to trial-fit and trim the cowl until it fits over the engine.

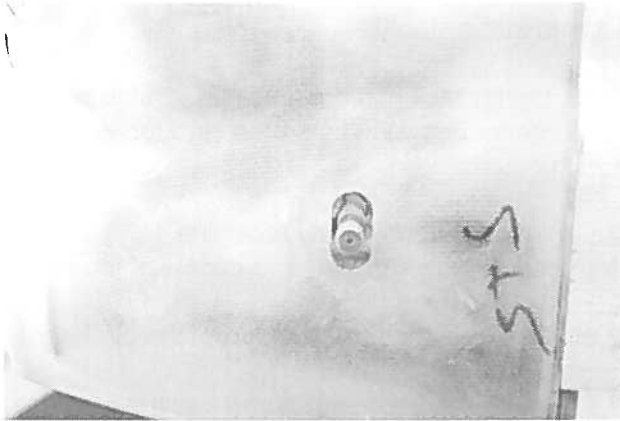
**12.81.** So you're going along fitting the cowl over the engine. You're trimming off fiberglass, cutting holes for the valve cover, drilling holes to locate the needle valve and you mis-drilled the hole for the needle valve. Don't panic. This isn't the end of the cowl!



Mis-drilled Hole In Cowl

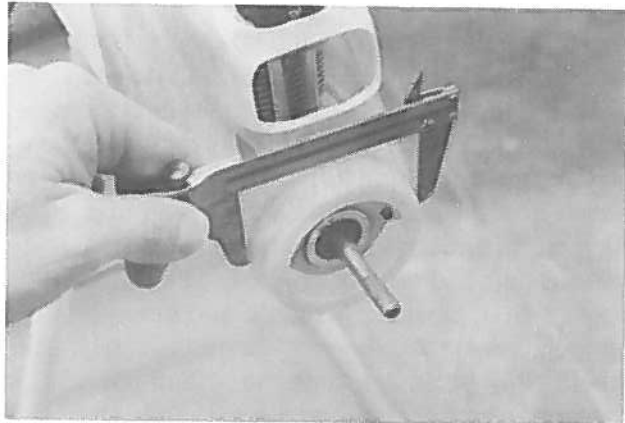
**12.82.** Use material removed from another portion of the cowl, trim it down, epoxy it to the back of the mistake. Wait for the epoxy to cure. Fill the void

area of the mistake with more epoxy. Wait for the epoxy to cure and sand it flush with the outside of the cowl. Presto ... a nice fix! This is a technique you can use anytime you make a mistake on a fiberglass component. (We've made mistakes and used this repair technique a number of times!) Nobody will notice a patch on the inside of a fiberglass component. If you really want to clean up the patch on the inside, sand and blend it into the surrounding area.



Repair Of The Mis-drilled Hole In The Cowl

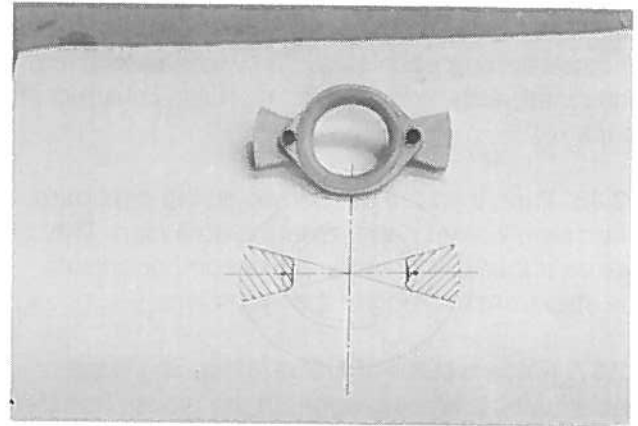
**12.83.** Usually, engine mount systems come with a nose ring. Install the nose ring on the engine. Install the cowl over the engine. At the location of the nose ring, measure the diameter of the cowl.



Diameter Measurement Of The Cowl At The Nose Ring

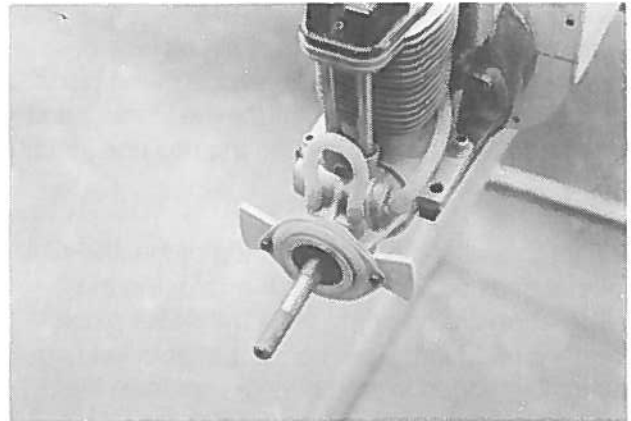
**12.84.** Draw a circle the diameter of the cowl at the nose ring with a compass. Lay the nose ring over the center and draw the required support tabs for

the nose ring. Fabricate the support tabs from 1/8" aircraft plywood.



Template For Nose Ring Support Tabs

**12.85.** Install the nose ring/support tab assembly on the front of the engine.



Nose Ring/Support Tab Assembly On Engine Front

Install the cowl over the engine and nose ring/support assembly. Install the spinner backplate. Check for clearance. This is another trial-fit-remove-trim process. The backplate should align with the cowl front and there should be a small gap between the cowl rear and the fuselage. Once you are satisfied with the fix, tack epoxy the support tabs in place. We remove the spinner back plate, dab a small bit of epoxy on each tab, install the spinner back plate and then hold the back plate in place until the epoxy has cured. Disassemble everything very carefully, reassemble it carefully and check the clearances. If all is correct, permanently epoxy the tabs in place.

## HORIZONTAL STAB CONSTRUCTION

If you need more help constructing the horizontal stab, refer to the wing construction section for photos showing each step. The wing, vertical and horizontal stabs follow the same basic construction steps.

**12.86.** Tape the stab plan down on the pin board. Then tape waxed paper over the stab plan. The waxed paper prevents the balsa components of the stab from bonding to the stab plan.

**12.87.** Place a piece of 1/2"x1/4" leading edge balsa over the leading edge on the plans. Transfer the locations of the stab ribs onto the 1/2"x1/4" balsa leading edge. Follow the same procedure for the trailing edge.

**12.88.** Pin a piece of 1/4"x3/4" balsa over the leading edge of the plans. Also, pin a piece of 1/4"x1/4" balsa over the trailing edge of the plans. These pieces are used to elevate the leading and trailing edges over the plans so the ribs don't touch the plans.

**12.89.** Pin the leading edge on top of the 1/2"x3/4" piece already pinned to the pin board. Pin the trailing edge on top of the 1/4"x1/4" balsa piece already pinned to the pin board. Let both leading and trailing edges extend over the ends on the plan. You will cut off the excess later.

**12.90.** Place the stab ribs between the leading edge and trailing edge. It will be necessary to sand the proper angle on the tip of the ribs to fit in the proper locations. Insert the stab tube into the ribs.

**HOWEVER, DON'T CUT OR GLUE THE STAB TUBE IN YET!**

**12.91.** Using a drafting or carpenter's square, adjust the ribs so they are all square to the building surface. The friction of all the balsa pieces should hold everything together while you perform this step. If not, use pins. Once you have checked and

double-checked that all the ribs are square, glue them in place.

**12.92.** The adjustable stab tube assembly consists of an 11" phenolic and aluminum tube and a pair of stab adjusters. Remove the aluminum tube from inside the phenolic tube. Cut a piece of phenolic tube approximately 2" long from the 11" tube. Cut the remaining 9" of tube into two pieces approximately 4-1/2" long. The 2" tube will be installed in the fuselage. The 4-1/2" pieces will be installed in the stab.

**12.93.** Lightly tack glue the two, 4-1/2" stab tubes to the interior ribs. Don't glue the stab tubes to the root rib.

**12.94.** At the root rib, lightly tack glue 1/4" balsa scrap blocks to the tip, tail, and middle of the rib.

**12.95.** Remove the stab frame from the pin board.

**12.96.** Insert the 2" phenolic tube into the fuselage. Slide the aluminum tube through the fuselage stab tube. Slide the stab onto the aluminum stab tube. Gently slide the stab root rib against the fuselage until the 1/4" blocks rest against the fuselage. This might require breaking the glue joint between the root rib tip and the leading edge.

**12.97.** Measure from the stab tips to the front center of the airplane. Adjust the stab halves forward and backward as necessary until the distances from each tip to the front center of the airplane are equal and the 1/4" adjusting blocks are resting against the fuselage side. (See the "Alignment" section for further description on triangulation and alignment). When the balsa blocks rest against the fuselage and the triangulation measurements are equal, lightly tack glue the 1/4" balsa blocks to the side of the fuselage. Again check to make sure the triangulation dimensions are equal and the balsa blocks are against the fuselage. Then glue the root rib to the leading edge. When you are done, break the tack glue joint between the fuselage and the

scrap blocks and then remove the stab panels. Remove the phenolic tube from the stab.

**12.98.** Install the elevator servo box and stab adjusters.

**12.99.** Install a balsa block sized to slide between the root rib, the first rib, back of the elevator servo box and trailing edge. This block offers additional support for the removable stab tube. First, rough cut the balsa to slide between the ribs. Next, using a 1/2" brass tube, bore a hole through the balsa block. Slide the balsa block into place. Slide the phenolic stab tube through the root rib, through the balsa block and then through the first rib. Shape the balsa block to the contour of the adjoining ribs with the stab tube in place (but not glued). Be careful, don't sand the adjacent ribs. It is easier to mark the profile of the ribs on the block, remove the block and then cut to the line. Trial-fit and check the block as you continually remove excess material.

**12.100.** Install the stab sheeting (to prepare the stab sheeting, see the chapter on foam core wing construction). Before installing the stab sheeting, locate the ribs and wing spar and draw light lines with a felt tip marker on the sheeting. This will help locate the ribs when you pin the sheeting to the ribs.

Re-pin the stab structure over the plan on the pin board. Using an epoxy brush, paint slow-cure epoxy on the top of all the ribs, wing spar, and wing tube supports. However, don't glue the root rib to the sheeting. Use lots of pins to hold the sheeting in place. Once you think you have placed all the pins you need, press gently between the pins on the sheeting and listen to hear (and feel) if the sheeting rebounds. If it sounds and feels solid you're okay. If it rebounds, install more pins. You want to make sure all the surfaces are mated properly.

**12.101.** The stab panels are now ready to receive the other piece of stab sheeting. Lay the panel in

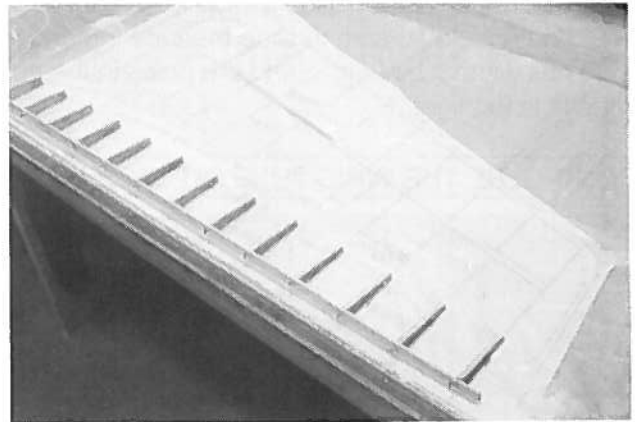
the stab jig, pin it to the board and glue the sheeting down the same way as noted previously.

## WING CONSTRUCTION

**12.102.** Place a very flat pin board on a very flat surface. We have been successful in using a solid core door as a work surface and the back of a 2'x4' acoustical ceiling tile for a pin board.

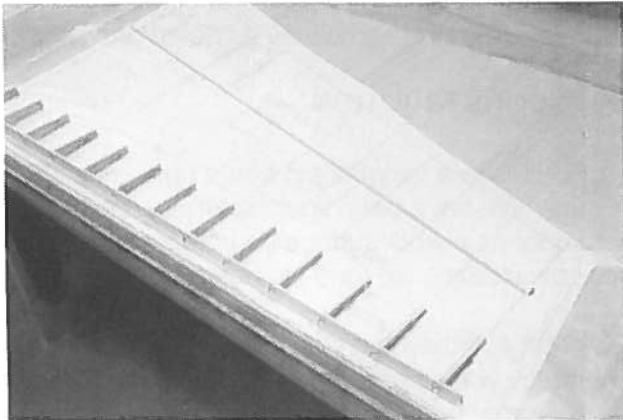
**12.103.** Tape the wing plan down on the pin board. Then tape waxed paper over the wing plan. The waxed paper prevents the balsa components of the wing from becoming bonded to the wing plan.

**12.104.** Build the trailing edge wing jig as per the plans. Pin the wing jig down to the plans in the proper location.



Wing Plan, Waxed Paper and Wing Jig Pinned to Ceiling Tile

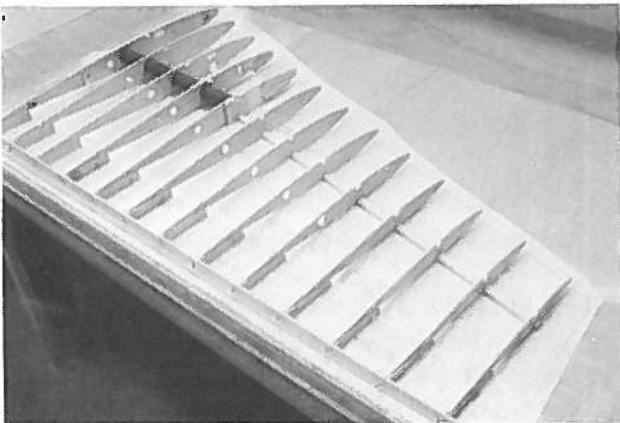
**12.105.** Pin a 3/8"x1/4" wing spar down over the wing plan in the proper location. Let it extend over each end of the wing spar as noted on the plan. You will cut off the excess later.



Wing Spar Pinned To Board

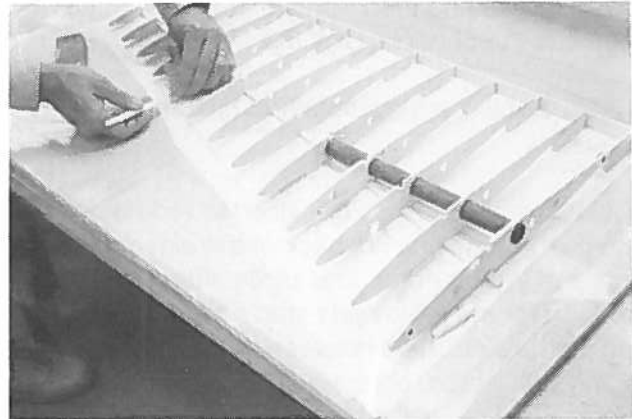
**12.106.** Place the wing ribs on the wing spar over the proper location as per the plan and pin them in position. Cut the wing tube to the proper length as noted on the plans and slide it into ribs W1 through W5. You should be able to slide the tube into the wing ribs without binding. Sand the holes in the ribs if the fit is too tight.

**DON'T GLUE THE WING TUBE IN PLACE YET!**



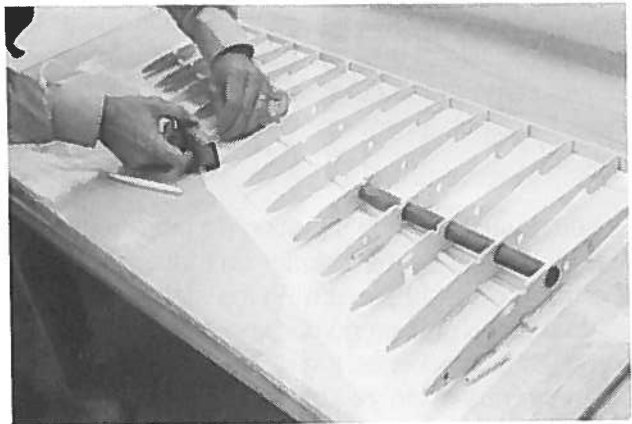
Wing Ribs Placed On Wing Spar And Jig

**12.107.** Using a drafting triangle or a carpenter's square, transfer the intersection of the wing rib with the leading edge onto the rib as per the plan.



Transfer Intersection Of Rib Tip with Leading Edge

**12.108.** Sand the tip of the ribs to the proper angle and to the line marking the leading edge.

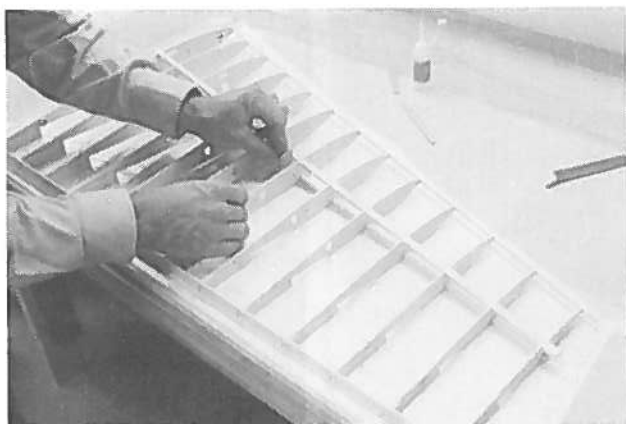


Sanding Rib Tips To The Leading Edge Angle

**12.109.** This next step varies from what's shown on the plans. The plans indicate 1/16" balsa pieces inserted between the ribs. We cut a 1/16" balsa cap strip the length of the leading edge and width of the fronts of the wing ribs. We use our method because it allows us to extend the sheeting over this cap strip. We then sand the sheeting back to the cap strip. The leading edge is butted to the edge of the sheeting without a gap.

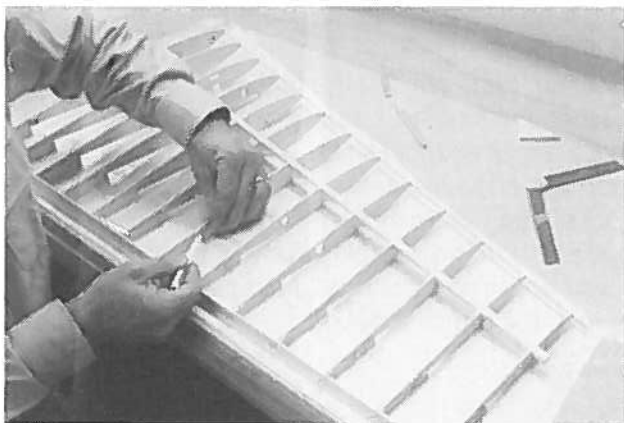
Cut a cap strip from 1/16" balsa approximately 48" long and approximately 5/8" wide. Place the cap strip over the plans and mark where the front tips of the ribs are to be located. Place the strip on the front of the wing ribs and glue it in place.

**12.110.** Place the top wing spar in the notch in the top of the ribs. Using a drafting or carpenter's square, adjust the ribs so they are square to the building surface. The friction of all the balsa pieces should hold everything together while you perform this step. Once you have checked and double-checked that all the ribs are square, glue them in place. However, don't glue the root rib to both wing spars; glue only the root rib to the bottom wing spar at this time. We want the root rib free to move. A few steps from now we will fit the wing to the fuselage. We will then glue the root rib to the other wing spar, sheeting, and the wing tube.



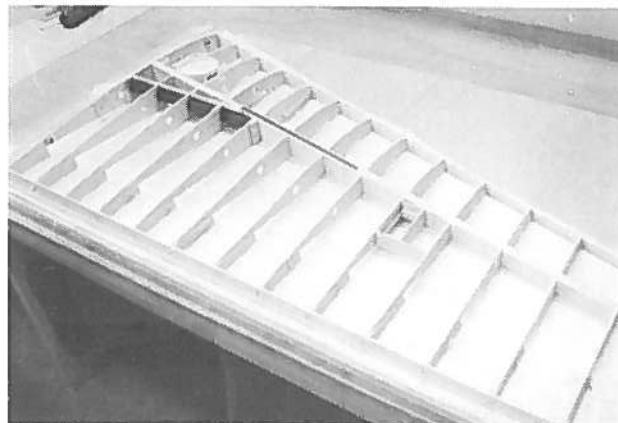
Ensuring Ribs Are Square Before Gluing In Place

**12.111.** Transfer the location of the aileron facing surfaces onto the ribs using a drafting square and a fine tip marker (the same way you transferred the leading edge location onto the front of the ribs).



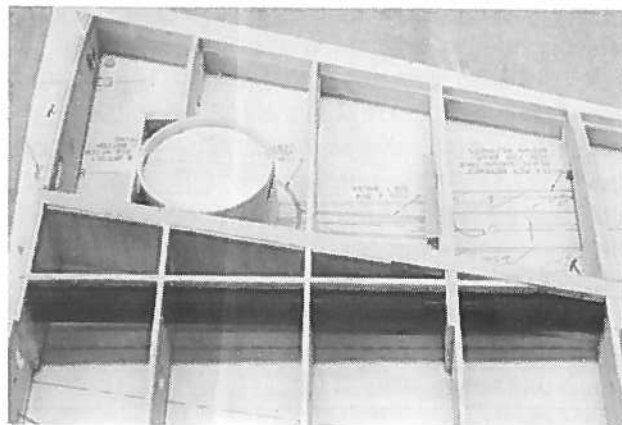
Transfer Aileron Facing Location To Wing Ribs

**12.112.** Install the shear panels between the ribs, the carbon fiber on the top wing spar and wheel well assembly.



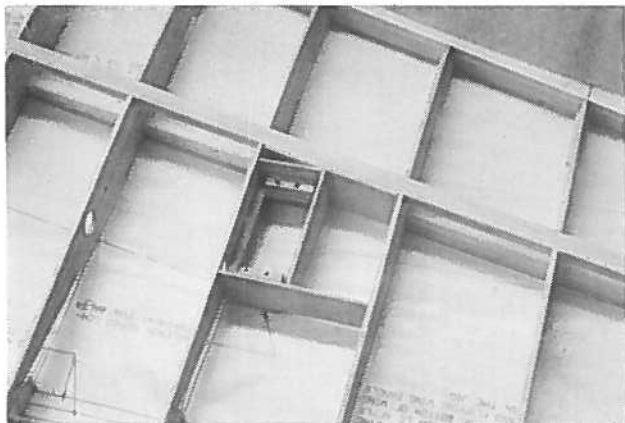
Shear Panels, Wing Tube And Carbon Fiber Installed

**12.113.** Epoxy the wing tube in place to all the ribs except the root rib. Install the necessary shear supports.



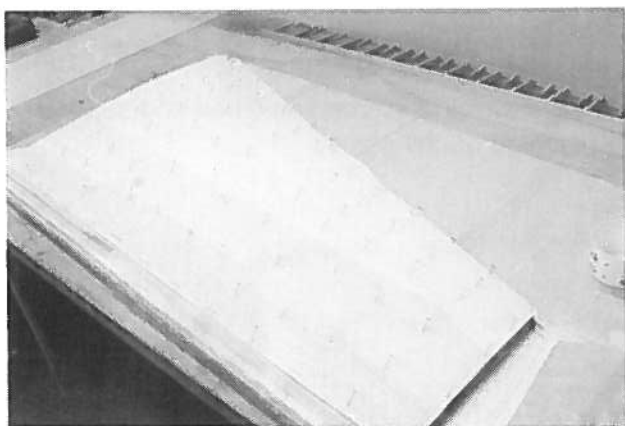
Wheel Well, Wing Tube and Supports Installed

**12.114.** Install the aileron servo box and supports as indicated on the plans.



Aileron Servo Support Box Installed

**12.115.** Install the wing sheeting (to prepare the wing sheeting, see wing and stabilizer sheeting in the "Wing and Stabilizer" chapter). Before installing the wing sheeting, locate the ribs and wing spar on the sheeting and draw light lines with a felt tip marker on the sheeting. This will locate the ribs when you pin the sheeting down to the ribs. Paint slow-cure epoxy on the top of all the ribs, wing spar, and wing tube supports using an epoxy brush. However, don't glue the root rib to the sheeting except at the wing spar area. Use lots of pins to hold the sheeting in place. Once you think you have inserted all the pins you need, press the sheeting gently between the pins and listen to hear and feel if the sheeting rebounds. If it sounds and feels solid, you're okay. If it rebounds, install more pins. You want to make sure all the surfaces are mated properly.

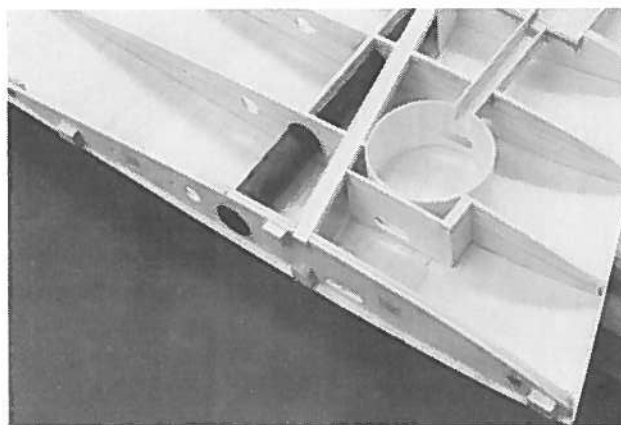


Wing Sheeting Installed With Lots Of Pins

**12.116.** Remove the wing panel from the pin table and the wing jig. Sand the leading edge flush with the cap strip on the tip of the wing ribs. Sand the sheeting overhanging the wing tip rib flush with the wing tip rib. Don't sand the sheeting overhanging the root rib. The excess will be removed after joining the wing to the fuselage.

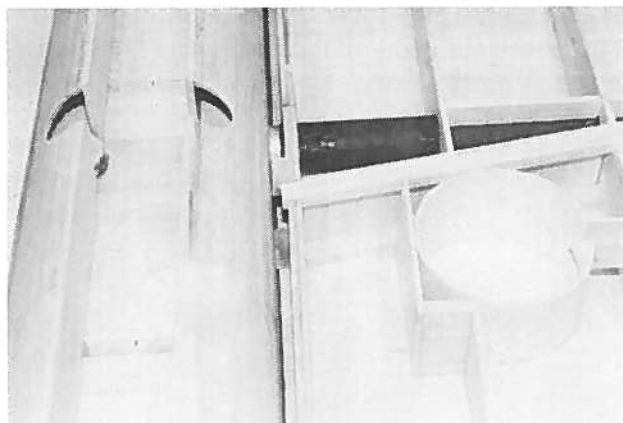
**12.117.** Build the other wing panel, repeating all the wing construction steps listed above. Now you are ready to fit the wing panels to the fuselage.

**12.118.** At the root ribs, install 1/4" balsa scrap blocks on the face of the rib. Glue them lightly to the tip, tail, top and bottom of the ribs.



1/4" Scrap Balsa Stand Off Blocks Tack Glued To Root Rib

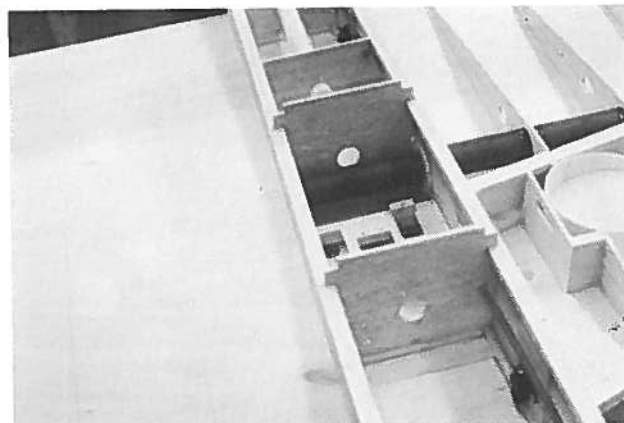
Insert the phenolic wing tube inside the fuselage. Slide the aluminum tube through the fuselage and wing tube. Gently slide the wing panels onto the tube until either the 1/4" root rib blocks, or the sheeting, rests against the fuselage. If the sheeting touches the fuselage, slowly remove the sheeting until the root rib blocks rest against the fuselage near the wing tube area. Ultimately there should be a small gap (approximately 1/16") between the fuselage and the sheeting. Take your time and go slowly. Repairing this problem isn't easy if you remove too much sheeting.



Root Rib Being Mated To Fuselage

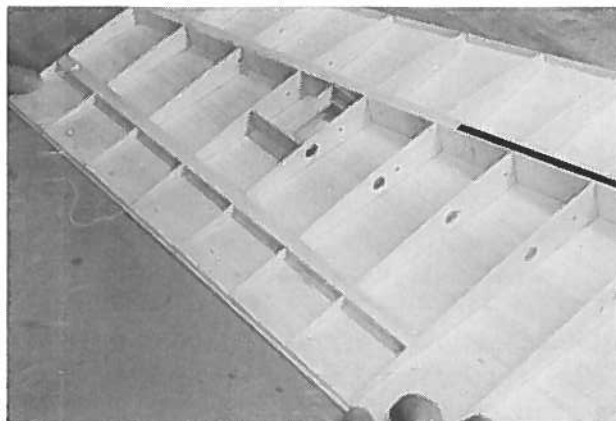
**12.119.** At the same time you are adjusting the gap between the fuselage and the sheeting, triangulate the dimensions from the wing tips to the rear center of the airplane. (See the alignment chapter for a further discussion on triangulation and alignment.)

**12.120.** Work back and forth between the triangulation measuring and the removal of the sheeting. When the balsa blocks rest against the fuselage and the triangulation measurements are equal, lightly tack glue the 1/4" balsa blocks to the sides of the fuselage. Again check to make sure the triangulation dimensions are equal, the balsa blocks are against the fuselage and there is a small gap between the sheeting and the fuselage. Then glue the root rib to the wing sheeting. When you are done, remove the wing panel. Very carefully remove the excess sheeting and the 1/4" balsa blocks. When you are done, the wing root rib should fit perfectly to the fuselage with no gap. If done right, there is a beautiful fit between the wing and fuselage.



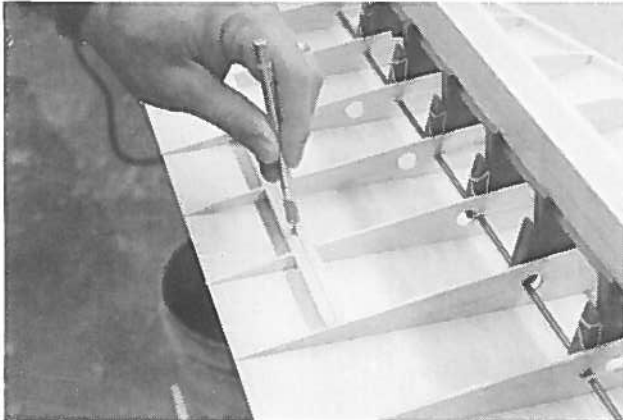
Joint Between Wing And Fuselage w/ No Gaps

**12.121.** Remove portions of the wing ribs that the aileron facing strips will occupy. Cut the aileron facing strips to length and shape them to contour the airfoil configuration. Once satisfied with the fit, glue them in place. Don't glue the faces of the strips together. Glue only the strips to the sheeting and the ribs.



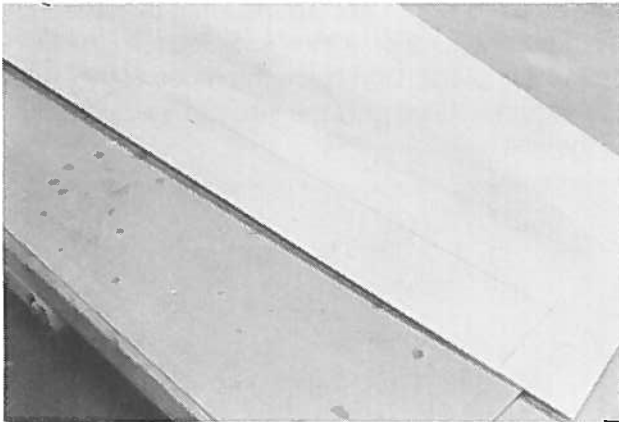
Installing Aileron And Wing Facing In The Wing

**12.122.** Mark the centerline location of the aileron facing. Slide an X-Acto knife blade into the facing joint penetrating the sheeting. Using a felt tip marker, mark where the X-Acto blade penetrated the sheeting. Mark the joint location at a couple of places on the sheeting.



Establishing Joint Between Aileron and Wing

**12.123.** Draw a line with a fine tip felt tip marker, connecting the marks.

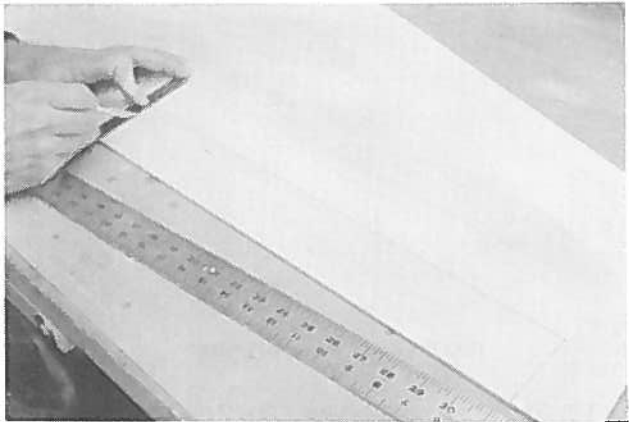


Marking The Joint Between The Aileron And Wing

**12.124.** The wing panels are now ready to receive the other piece of wing sheeting. Lay the panel in the wing jig, pin it to the pin board and glue the sheeting onto the ribs, leading and trailing edges the same way as noted previously. Check to make sure that all the following components have been installed prior to installing the sheeting:

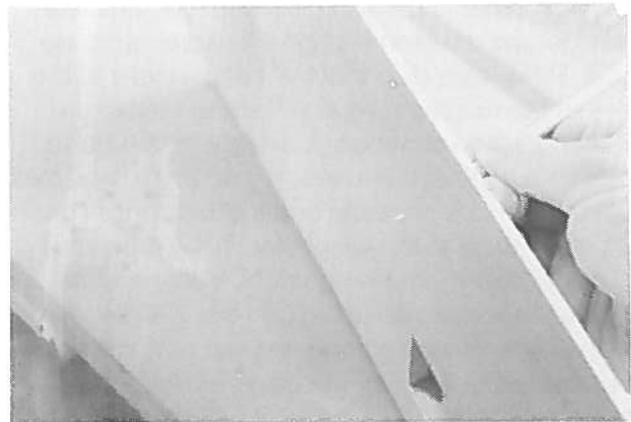
- The Landing Gear Blocks;
- Wheel well openings and gear enclosures;
- Aileron Servo Boxes;
- Carbon fiber strips; and the
- Balsa Backing for the Aileron Horns.

**12.125.** Using a straight edge and a sharp X-Acto knife, cut the sheeting on the hinge joint between the aileron and the wing.



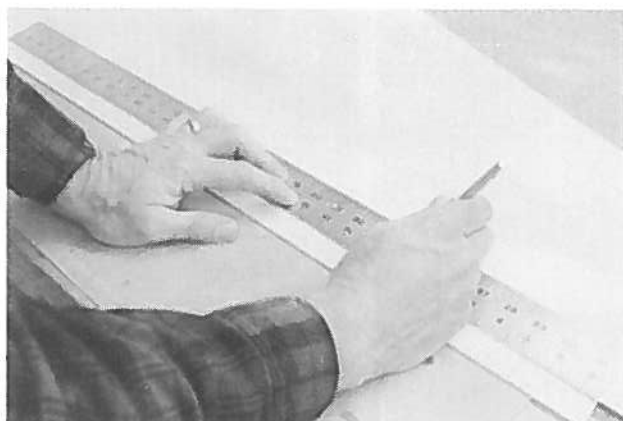
Cutting The Sheeting At The Aileron And Wing Joint

**12.126.** Insert an X-Acto knife blade in the aileron/wing hinge joint previously cut and penetrate the piece of sheeting you just installed. Mark the location with a fine tip felt marker. Do this in a number of locations as noted previously.



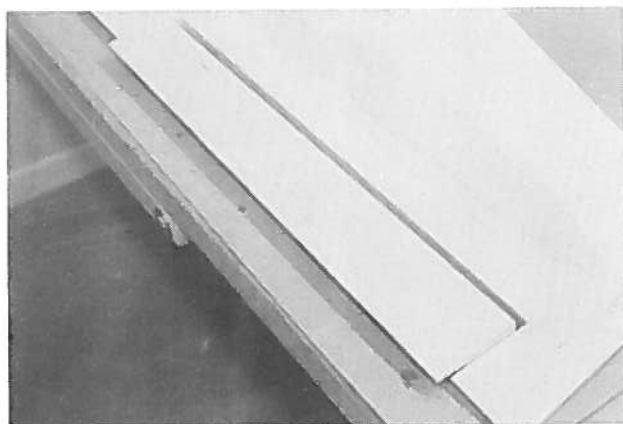
X-Acto Blade Marking Aileron Joint On Sheeting

**12.127.** Connect the marks on the sheeting with a fine tip felt marker. Cut on this line and remove the aileron from the wing panel.



Cutting Aileron From The Wing Panel

**12.128.** Once the aileron is cut from the wing panel, sand the edges lightly.



Aileron Cut From Wing Panel And Sanded Lightly

**12.129.** Establish the hinge line on the wing panel and aileron. Sand a 30° bevel on the aileron face. Cut slots for the aileron hinges using a Tetra Hinging Tool. A simple slit with an X-Acto knife in conjunction with the Tetra Hinging Tool and Easy Hinges produces excellent results.

### FINAL ASSEMBLY BEFORE FINISHING

We always assemble the airplane before beginning the finishing process on our airplanes. We treat this step as though it were the final assembly of the airplane; everything from the spinner to the tail wheel is installed.

We have found that during the final assembly, certain components sometimes don't fit together properly. This assembly process gives us the chance to make modifications before the model is finished. We avoid compounding problems by not having to concern ourselves with refinishing the airplane if we must make a modification.

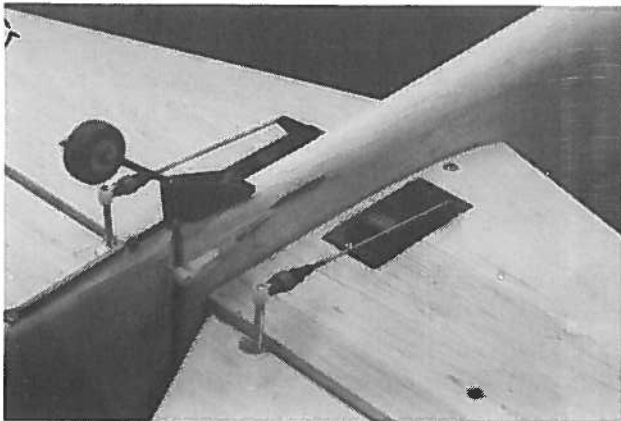
When we assemble the airplane, we tend to get carried away and start swinging the monster around without paying attention to where we're swinging. Before we know it, BANG! A ding! If the airplane is not finished, no big deal ... Fill it and keep going.

By the time we've finished an airplane, we've experienced two emotions: The first is impatience; we want to get the project done. The second is elation and the desire to fly. But with all the components cut and fit, we can curb the final assembly emotions and the time needed to assemble is minimal.

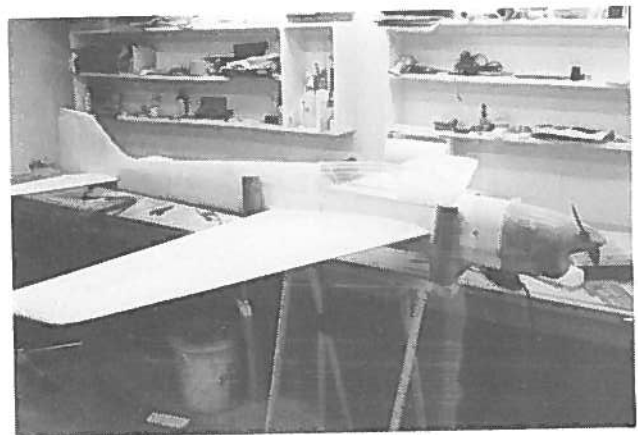
**12.130.** The following are pictures of the airplane before finishing and after all the components are installed.



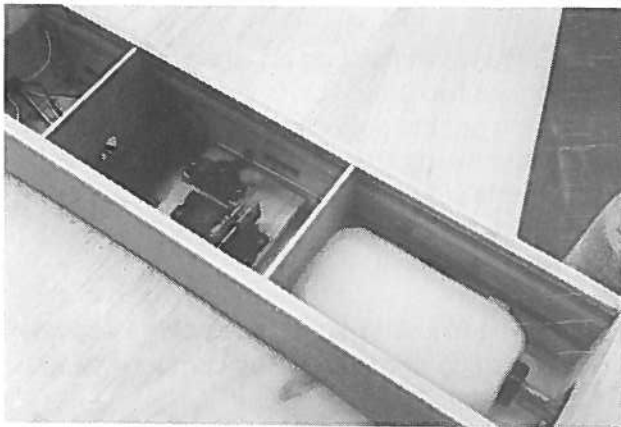
Engine W/ Fuel Lines And Throttle Linkage Installed



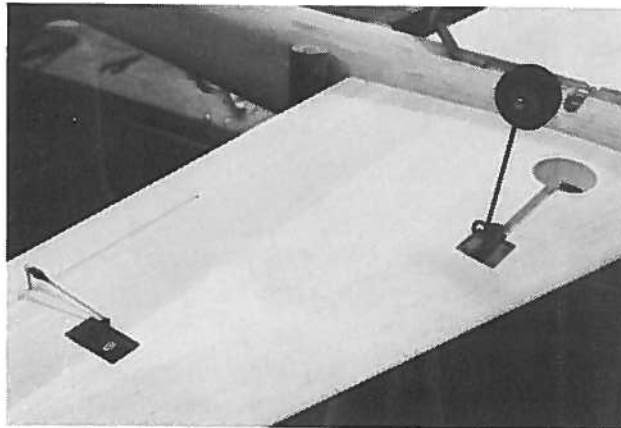
Elevator Servos, Rudder Linkage And Tail Wheel Installed



Airplane Completely Assembled W/ Canopy Set In Place



Fuel Tank, Retract And Engine Servo And Receiver/Battery Installed

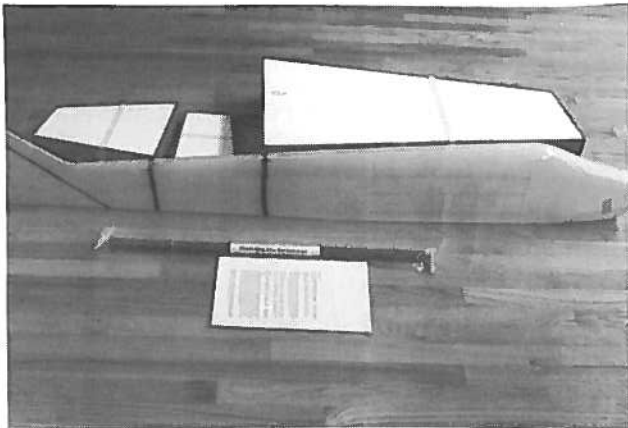


Aileron Servo And Retract System Installed

## Chapter 13 PROPHECY

### GENERAL

The Prophecy, designed by Dave Guerin is derived from a long line of airplanes originating with the Jeckyl designed by Meryl and Chip Hyde. The kit is manufactured and distributed by Piedmont Models (For their address see Appendix C).



Prophecy Kit

The Prophecy is another state-of-the-art pattern airplane that is very popular. It has been successfully flown by a number of elite pattern flyers to very high results in both the United States Nationals and also the World Championships.

The building techniques used for the Prophecy are also applicable to the following airplanes:

Jekyl  
Dr. Jekyl  
Dr. Jekyl PhD  
Sequel

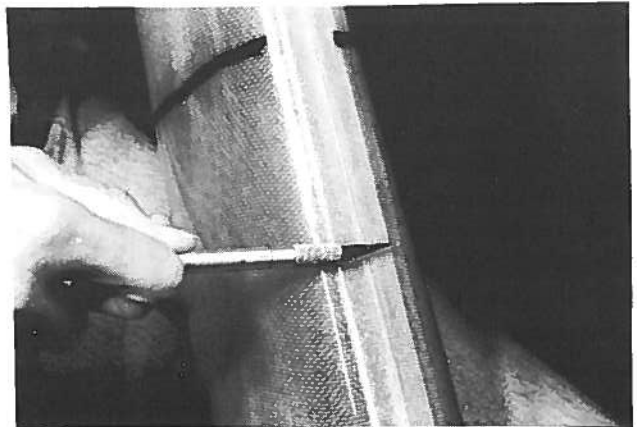
### FUSELAGE PREPARATION

Wash the fiberglass components thoroughly with alcohol. This is done to remove any of the release agents that might be present on the

outside of the fuselage. Give it a good scrub both inside and out to be assured that all the release agents have been removed. Don't use soap and water. The soap will leave a residue on the surface that can consequently complicate the building and finishing process. Once washed thoroughly, dry it with a towel or in the sun.

Most fiberglass fuselage components have a ragged joint or seam that needs to be removed and filled with appropriate filler.

**13.1.** With the back of an X-Acto knife blade scrape the excess fiberglass resin down to the fuselage. This step will not make the seam smooth; it is done to eliminate the excess material.



Removing Excess Material From Fuselage Seam

**13.2.** Using 200-grit wet/dry sandpaper mounted on a sponge block, sand the seam. The proper technique is not to sand parallel to or with the seam, but to cross the seam at a 45° angle. Sand so a flat spot is not formed on the seam. In addition, be careful not to remove the gel coat from the surrounding areas. The purpose of the gel coat is to give the fiberglass parts a smooth finish. If you sand too much, pinholes will form, which will cause problems when you finish the airplane.

**13.3.** Apply automotive glazing putty body filler to the seam. You need not apply big clumps of the stuff. All you want to do is fill in any depressions at the seam. The glazing putty we like is Evercoat. We find it easy to use and fairly lightweight in comparison to other body fillers. You can purchase Evercoat glazing putty (two part) at your local auto body repair store.



Applying Body Filler To Prepared Fuselage Seam

**13.4.** Sand off the excess body filler using the same sanding technique as explained previously.

**13.5.** Inspect the fuselage and all other fiberglass parts for pinholes. If you find pinholes, fill them with polyester glazing putty or Prather pinhole filler and sand smooth.

**13.6. (OPTION)** As an option prior to performing an extensive amount of work on the fuselage, prime it and all fiberglass parts and then inspect for pinholes. We find that once a fiberglass part is primed the pinholes become very apparent. If the fuselage is full of pinholes, you can contact the manufacturer and obtain another. However, if you have installed the firewall, horizontal stabilizer, belly cover, chin cowl and wings, it's very difficult to send that fuselage back for another. To prime the fuselage, first buff it with a Scotch Brite Pad; this only removes the gloss from the gel coat.

**13.7. (OPTION)** Mix primer and apply it on the fiberglass parts with a brush or spray system.

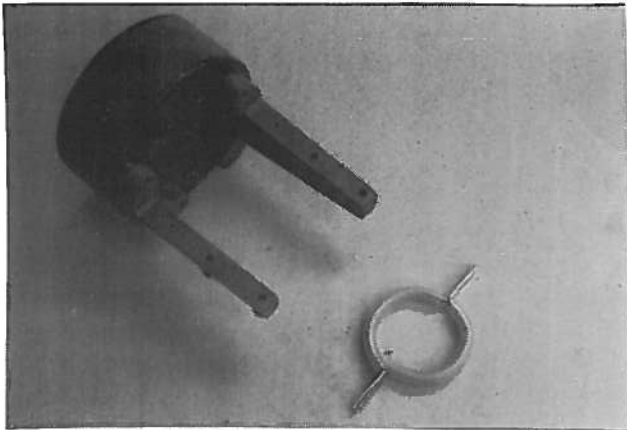
We mix the two parts of K & B primer and then add micro balloons until it has a slurry consistency. We then brush it on the seam. We brush a little more on areas with very small pinholes. Don't worry about the runs or drips. All the excess will be sanded off before the final coats of paint are applied.

**13.8. (OPTION)** Once the primer has dried, sand it down and inspect for pinholes. If all pinholes have been filled in, you can continue. If there are pinholes remaining, apply more polyester glazing putty. If there are a lot of holes, contact the manufacturer and obtain a replacement part or parts. Remember, body filler does weigh something, and the more you put on, the heavier the plane will become. Hold the application of the body filler to a minimum.

**13.9.** The Prophecy comes with the reference lines marked on the sides of the fuselage for the wings and horizontal stabilizers. If the reference lines are not drawn on the sides of the fuselage it will be necessary to establish these reference lines. Refer to "Wing Installation and Alignment" on page 44 for more details on how to establish these lines.

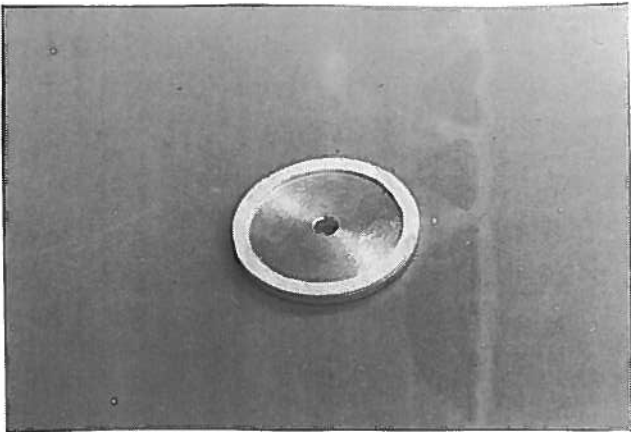
## FIREWALL AND ENGINE INSTALLATION

A soft mounted engine is the standard. The large engines used for the present day airplanes require soft mounting. There are many soft mount systems on the market. However, the Hyde mount is our preference.



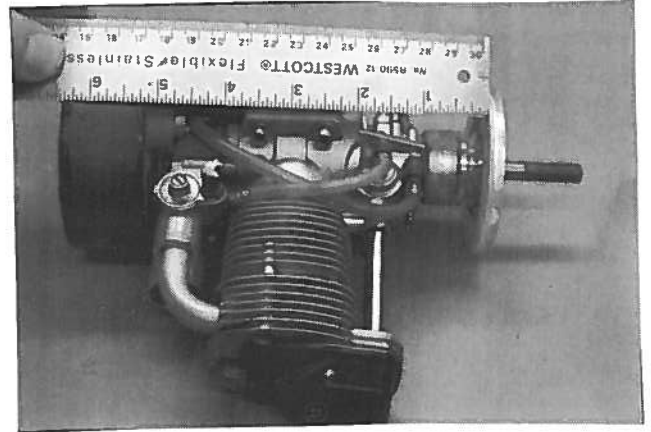
Hyde Soft-Mount For YS120 Engine

**13.10.** Make a spacer from 1/16" balsa sheet and tack glue it to the back of the spinner back plate. Trim the spacer so it is the same diameter as the spinner.



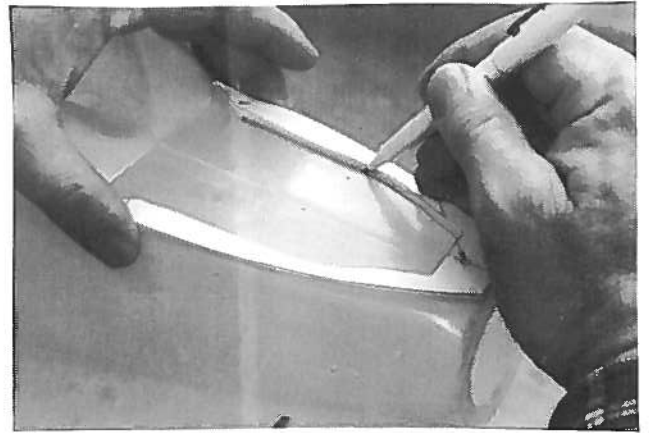
Spacer Ring Glued To Spinner Backplate

**13.11.** The Prophecy fuselage doesn't have any area removed for the engine installation and clearance. To identify this area, install the soft mount on the engine and install the spinner backplate with the 1/16" spacer onto the engine. Place the assembly next to the fuselage. Position the engine so the spacer on the back of the spinner is in line with the fuselage nose. Mark the fuselage at the back of the engine mount. These marks show roughly where the front of the firewall will be installed.



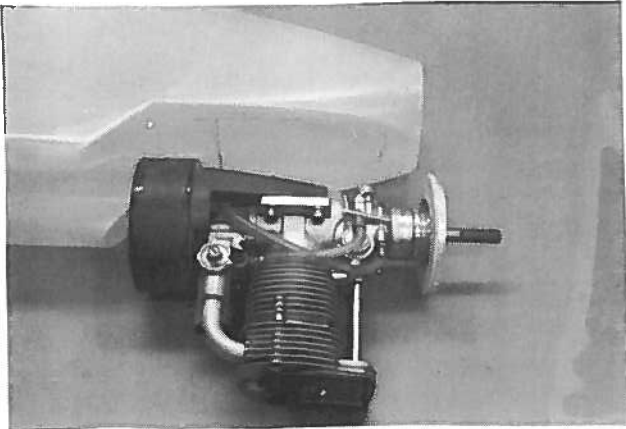
Locating Firewall W/ Engine &amp; Mount

**13.12.** Mark the location of the chin cowl former on the flat portion of the engine compartment.



Locating Chin Cowl Former On Bottom Of Engine Compartment

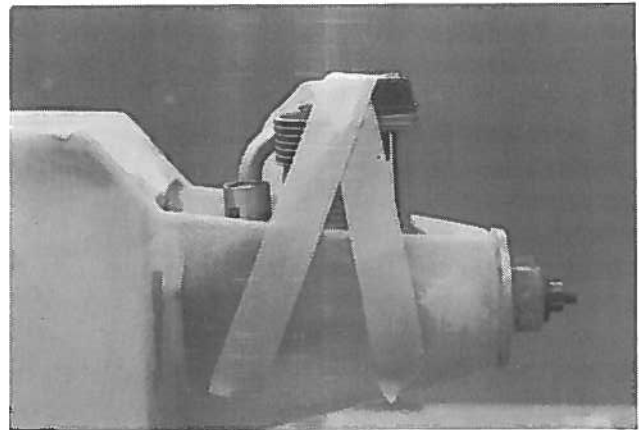
**13.13.** Mark the engine compartment area where the engine will protrude when final engine installation is complete. Be conservative; at this time don't remove an excessive amount of material, just enough to initially fit the engine into the fuselage.



Area To Be Removed For Engine Installation

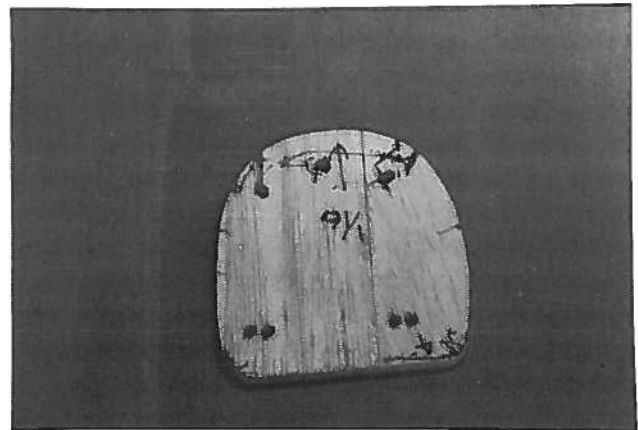
**13.14.** Sand and clean the inside of the fuselage at the area where the firewall will be attached.

**13.15.** Slide the engine into its compartment and install the engine on the mount. Install the prop and spinner backplate on the engine while the engine is in the engine compartment (use the hub of an old prop). Hold the fuselage upright and align the spinner backplate with the nose ring. Tape the spinner backplate securely in place against the fuselage nose. The assembly should be fastened firmly enough to permit turning the fuselage over and standing it on the spinner. By placing the spinner back plate directly on the fuselage front and using tape to secure it in position we automatically build in the manufacturers suggested right and down thrust. Most pattern fiberglass fuselages come with the correct thrust built into the fuselage nose. To demonstrate, look at the front of the fuselage from the top. You will note that the "spinner ring" on the fuselage is angled to the right. Utilize this built-in feature and the airplane will have the proper right thrust. During the trimming phase of flying the thrust can be varied easily, but for now build the airplane with the manufacturer's recommendation.



Engine/Mount Temporarily Installed

**13.16.** Cut a balsa template of the firewall from 1/8" balsa. We use balsa because it is easier to work with and less expensive than aircraft grade plywood. Trial-fit the template into the fuselage by dropping it on the back of the motor mount. It should lie on the back of the motor mount with a small gap between the fuselage and the template. If the template, or ultimately the firewall, presses against the fuselage during the assembly process, improper final alignment will result. Sand and fit the firewall template until you achieve the proper fit.



Firewall Template

**13.17.** While the firewall template is loose and still accessible, you may wish to locate and drill the holes for the throttle cable and the fuel lines.

**13.18.** Once you're satisfied with the template fit inside the fuselage, re-check the spinner

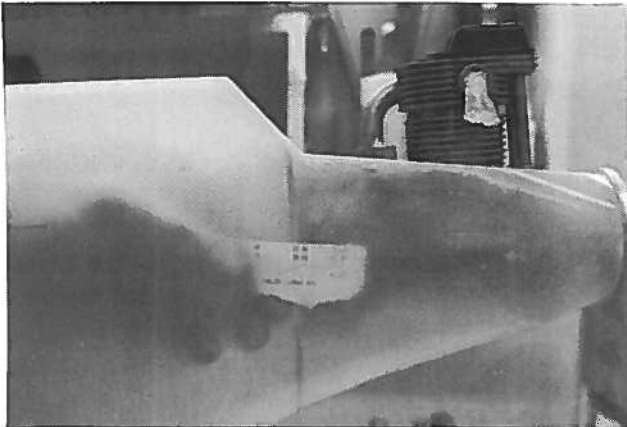
alignment. Rotate the engine so that the engine top will be in the center of the engine opening. Then secure the engine in this position with masking tape.

**13.19.** Remove the firewall template.

**13.20.** Using the balsa template, cut out a firewall from the appropriate material noted in the kit plans.

**13.21.** Stand the fuselage vertically on the spinner. Reach through the bottom opening and place the firewall template onto the backside of the motor mount.

**13.22.** Check the fit to ensure there is a small gap between the permanent firewall and fuselage sides.



Necessary Gap Between Firewall And Fuselage Side

If the assembly is done correctly, there should be a small gap (approximately 1/16" or less) between the firewall and the fuselage around the firewall circumference. The firewall must fit closely enough so that there isn't a large gap between the firewall and the fuselage, but shouldn't be in contact with the fuselage. If any portion of the firewall is pressing against the fuselage, mark the contact area on the firewall. Disassemble all the components, remove the excess material from the firewall and reassemble. An easy way to check the clearance is to slide a piece of paper between the firewall and the fuselage side. If at any point

the paper binds while sliding it around the firewall circumference, mark the point; remove the firewall and sand off the excess.

**13.23.** Once satisfied with the firewall fit and clearance, remove the firewall, and place a few drops of C.A. on the back of the motor mount. Drop the firewall onto the backside of the motor mount. Again check the firewall fit for clearance. If the clearance is correct let the C.A. cure.

**13.24.** Once the C.A. has cured, gently remove the motor from the motor mount without breaking the temporary bond between the firewall and the motor mount. Gently remove the motor mount and firewall assembly from the airplane via the bottom opening.

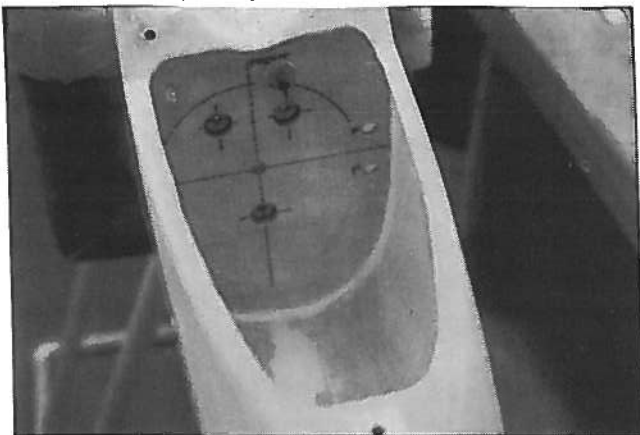
**13.25.** Drill holes through the firewall and install 4-40 bolts and blind nuts on the backside of the firewall using the motor mount as a template. Break the temporary bond between the firewall and the motor mount and install the blind nuts.

**13.26.** Fasten the motor mount to the firewall with the permanent bolts and blind nuts. Slide the firewall and motor mount assembly into the fuselage through the bottom opening. Fasten the engine to the engine mount. Install the spinner backplate, prop hub and spinner bolt onto the engine. Align the spinner backplate with nose ring on the fuselage and secure the engine in place with masking tape. If all aligns properly, epoxy the firewall to the fuselage at just a few spots with five-minute epoxy to hold it in place.

**13.27.** Once the five-minute epoxy has cured, gently remove the spinner assembly from the engine, the engine from the motor mount and the motor mount from the firewall.

The firewall may now be permanently glued in place with a mixture of forty-five-minute epoxy and micro balloons. Mix the epoxy and then add the micro balloons until it is a stiff paste. The stiff mixture can be worked and smoothed to create a nice fillet between the firewall and the

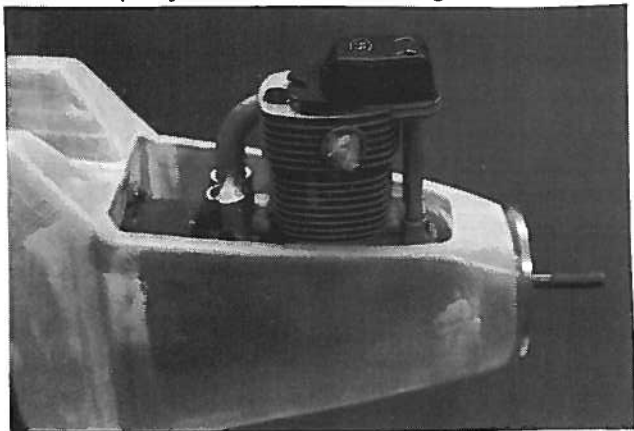
fuselage. When you apply the epoxy make sure you push it into the gap between the fuselage and the firewall. You'll know when you've filled the gap, because a dark line will appear on the outside of the fuselage where the epoxy has penetrated the gap. Don't push too hard and break the temporary bond.



Firewall Epoxied Permanently In Place

*Also, use only epoxy in the engine compartment of any airplane.* Epoxy doesn't break down under the influence of nitro methane, which is found in most airplane fuels. If you do use CA or other adhesives, our advice is to cover them with a coat of epoxy.

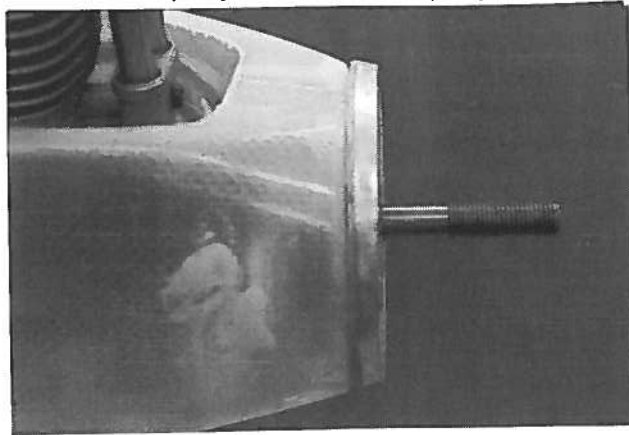
Let the epoxy cure for an evening.



Checking Clearance With Firewall Installed

**13.28.** Cut the front retainer ring holder from light-ply material.

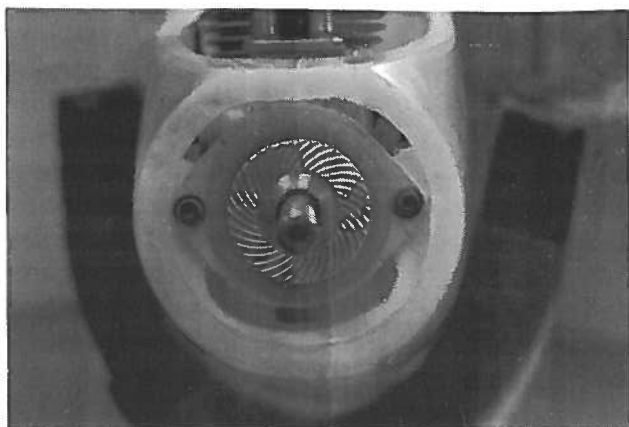
**13.29.** With the firewall epoxy completely cured and the motor mount installed, slide the retainer ring holder into the fuselage. Slide the retainer ring over the front of the engine. Slide the engine, with retaining ring attached, into the engine compartment and fasten the retaining ring to the retainer ring holder. Install the engine to the motor mount, spinner back plate, prop hub and prop nut. Check the alignment of the spinner ring and the front of the engine. With the spinner back plate properly aligned (against the front of the fuselage), the retainer ring and retainer ring holder in place (again there needs to be a small gap between the holder and the fuselage), epoxy the retainer ring holder to the fuselage. Do this at a couple of spots with some five-minute epoxy. Wait for the epoxy to cure.



Retainer Ring Tack Glued In Place With Engine Supported

**13.30.** Carefully remove the prop nut, prop hub, spinner back plate, retaining ring, engine and motor mount from the fuselage. Once again, using a mixture of forty-five minute epoxy and micro balloons, form a nice fillet of epoxy at the joint of the fuselage and the retaining ring holder.

**13.31.** Coat exposed wood areas of the firewall in the engine compartment with a thin coat of slow-cure epoxy. NOTE: You can reduce the viscosity of slow cure epoxy and also increase the set-up time by mixing in a small amount of alcohol into the epoxy.

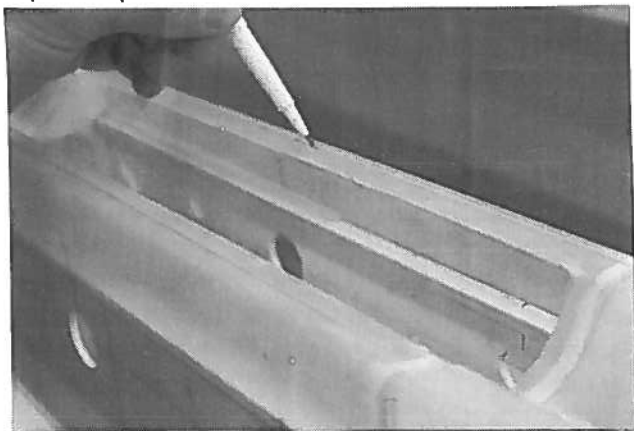


Installed Front Retainer Ring And Firewall

## FUSELAGE BOTTOM COVER

**13.32.** Fit the fuselage bottom cover to the fuselage. Remove any resin spots or flashing pieces interfering with the fit with an X-Acto knife, sandpaper or file.

**13.33.** Outline the perimeter of the fuselage bottom cover area with a fine line marking pen. This will allow you to see the location of the opening through the bottom cover when it is taped in place.

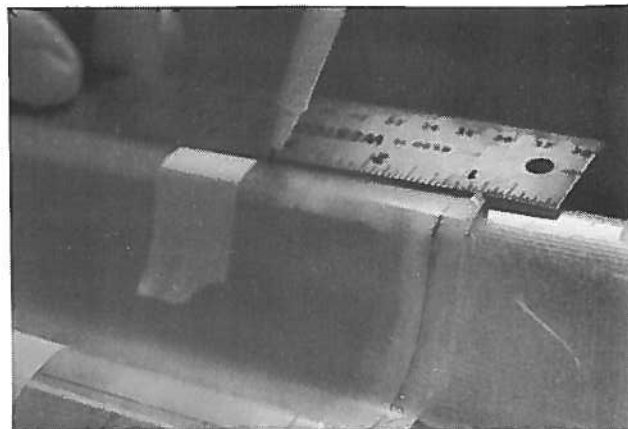


Outlining The Bottom Cover Area On The Fuselage

**13.34.** Using masking tape, secure the fuselage bottom cover to the fuselage in the final installed position. The fuselage bottom cover will be larger than the recess in the fuselage bottom. Mark the location of the fuselage edges on the fuselage bottom cover with a fine-line marking

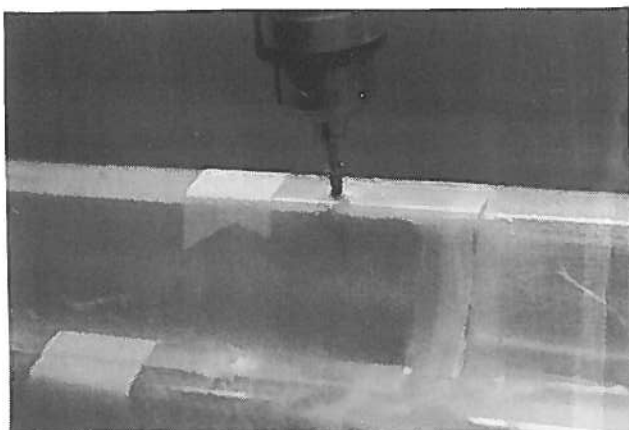
pen. Remove the fuselage bottom cover and trim the excess fiberglass leaving approximately a 1/8" of extra material. Again, using masking tape, secure the fuselage bottom cover to the fuselage and check the marks again. *Removing excess material the first time might change the fit of the fuselage bottom cover to the fuselage.* If the original lines are not correct on the bottom cover, wipe them off and draw new lines. Continue this trial-and-fit method until the fuselage bottom cover fits nicely in the fuselage recesses.

**13.35.** Tape the fuselage bottom cover in place and locate the attachment points. We recommend four 4-40 bolts for each side. Remember this cover might support the rear of the exhaust pipe. You also don't want this cover to vibrate while the engine runs.



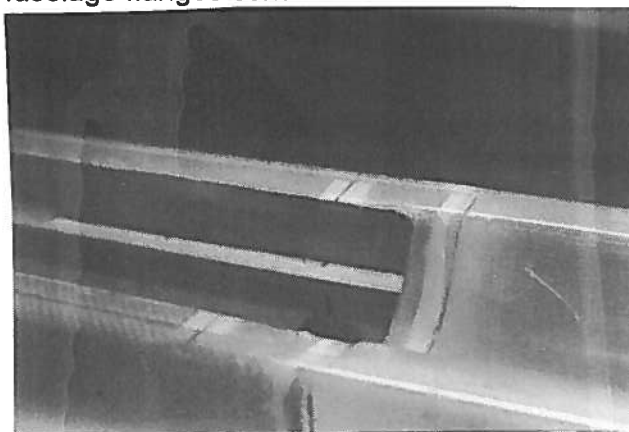
Locating Attachment Points For The Fuselage Bottom Cover

**13.36.** Drill a 1/8" hole through the mark on the bottom cover and through the flange on the fuselage. See steps 3.31 through 3.34, pages 15 and 16 for more details.



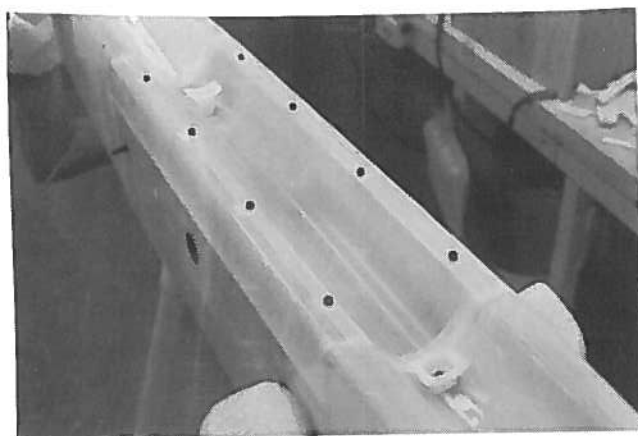
Drilling Holes For The Attachment Points

**13.37.** Remove the fuselage bottom cover and fasten 1/8" x 3/8" x 3/8" plywood plates on the fuselage flanges centered on the 1/8" holes.



1/8" Plywood Plates For Attachment Points

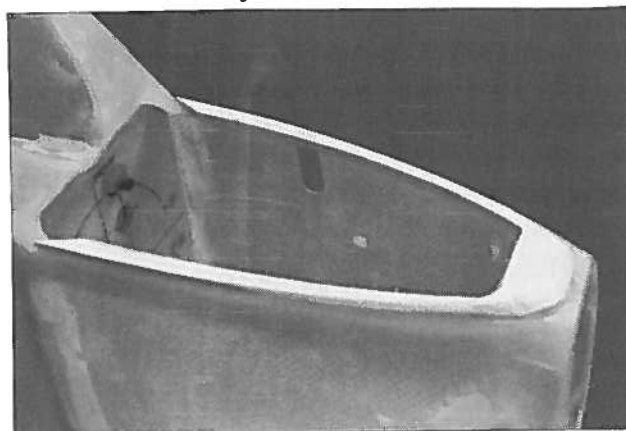
**13.38.** Drill through the plates when they're secure. Fasten a 4-40 blind nut into the plywood plate. You can now secure the fuselage bottom cover to the fuselage with a 4-40 bolt.



Bottom Cover Installed With 4-40 Bolts and Blind Nuts

## CHIN COWL

**13.39.** Place the chin cowl former on the fuselage and check for the proper fit. Sand the former if necessary.



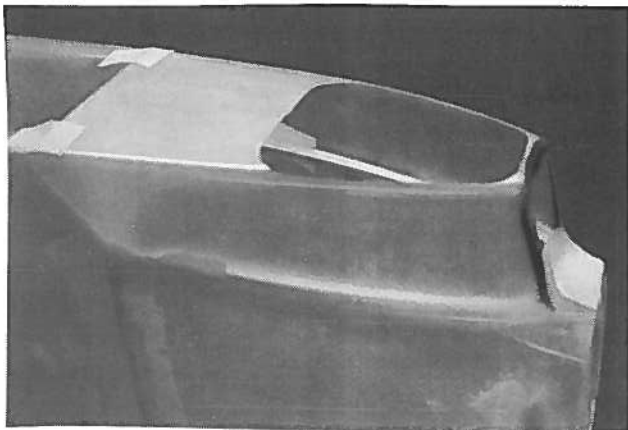
Chin Cowl Former Fitted To Fuselage

**13.40.** Fit the chin cowl to the fuselage and remove, with an X-Acto knife and sandpaper or file, any flashing, high spots of resin or fiberglass that prevent the chin cowl from fitting properly in its place.

**13.41.** Using masking tape, secure the chin cowl to the fuselage in the final installed position. The chin cowl will be larger than the area it covers. Mark the location of the fuselage edges on the chin cowl with a felt tip pen. Remove the chin cowl and trim the excess fiberglass. Leave 1/8" excess material. Again, using masking tape,

secure the chin cowl to the fuselage and check the marks again. Removing excess material might change the fit of the chin cowl to the fuselage. If the original lines are not correct on the chin cowl, wipe them off and draw new lines. Continue this trial-and-fit method until the chin cowl fits on the fuselage with the minimum gap between the two pieces.

**13.42.** Install the engine. Place the chin cowl over the engine and mark the areas to be removed. Cut out the areas for the cooling air intake into the front of the chin cowl and the cylinder head. *Be conservative and go slowly.* Continue to fit the chin cowl in its proper place, remove the fiberglass and trial-fit the chin cowl again. Continue this process until the chin cowl fits over the engine with enough clearance to allow for engine movement while properly fitting on the fuselage give it plenty of room. The engine will shake as much as 3/8" each direction at idle on a soft mount.



Cowl Cut Around Engine

**13.43.** Securely tape the chin cowl to the fuselage at the proper location. Make a mark with a felt tip pen on the fuselage and chin cowl where you will locate the front fastening point.

**13.44.** Drill a 1/8" hole through the mark on the chin cowl and through the flange on the fuselage. See steps 3.31 through 3.34, pages 15 and 16 for more details. Fasten 1/8" plywood plates in the proper locations on the fuselage and chin cowl. Drill through the plates. Fasten a 4-40

blind nut in the plywood plate on the fuselage. The chin cowl can now be secured to the fuselage with a 4-40 bolt.

**13.45.** Build the plywood chin cowl attachment supports that fasten to the fuselage. Refer to the plans for the dimensions to construct these attachment supports. Allow for the thickness of the chin cowl fiberglass when you locate these attachment supports. You want the chin cowl flush with the side of the fuselage. Glue these to the fuselage with epoxy.

**13.46.** When the attachment supports adhesive or epoxy has cured, tape the chin cowl in place. Locate the hole as per the plans. Drill a 1/8" hole through the chin cowl and attachment support. Remove the chin cowl and install a 4-40 blind nut on the backside of the attachment support.

**13.47.** Enlarge the front hole in the chin cowl *above* the bolt to accept the arrow shaft pieces making sure the holes are centered over the bolt. Drop the arrow shaft piece through the hole and butt it against the 1/8" plate used for the bolt back up. Once satisfied with the fit, glue the arrow shaft to the 1/8" plate at the bottom and at the top to the fiberglass chin cowl. Sand the top of the arrow shaft piece to match the contour of the adjacent area. Now you have a nice "chase" for your bolt.

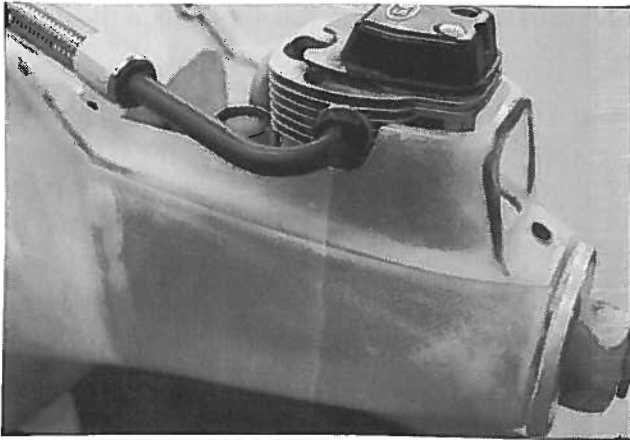


Chin Cowl Bolt Enclosures

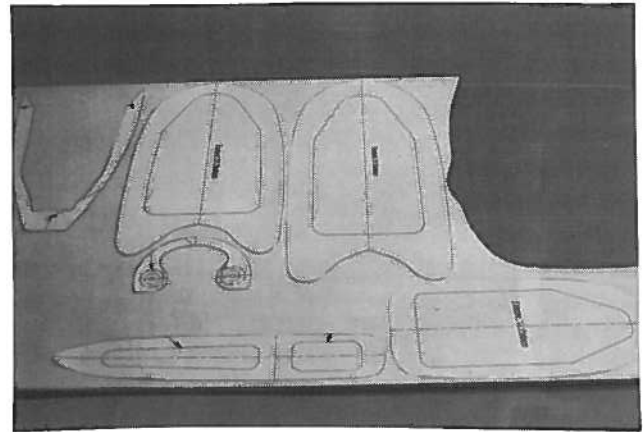
Note: We installed the fastening points as per the plans, installed the engine, trimmed the cowl

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for engine clearance, then we tried to bolt the exhaust header on the engine. Much to our surprise we had to make major modifications to not only the chin cowl but also the fuselage to allow for proper clearance around the pipe. The picture below shows you how we had to modify the fuselage and chin cowl. This is an example of what modifications you might have to make to accommodate your individual equipment clearances.

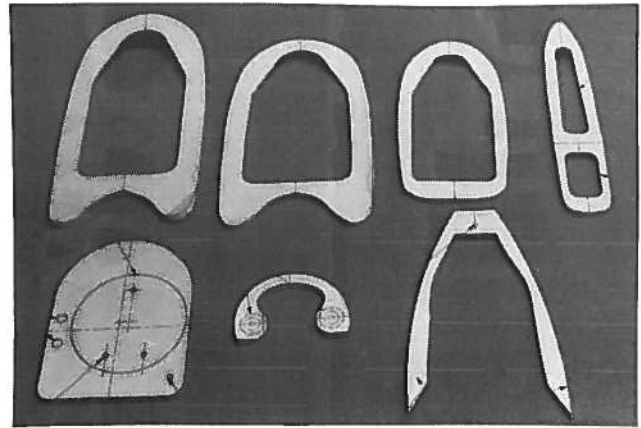


Chin Cowl, Engine and Pipe Installed In Fuselage



Bulkheads Pasted Onto Light Plywood

13.50. Cut out the bulkheads.



Bulkheads Cut From Light Plywood

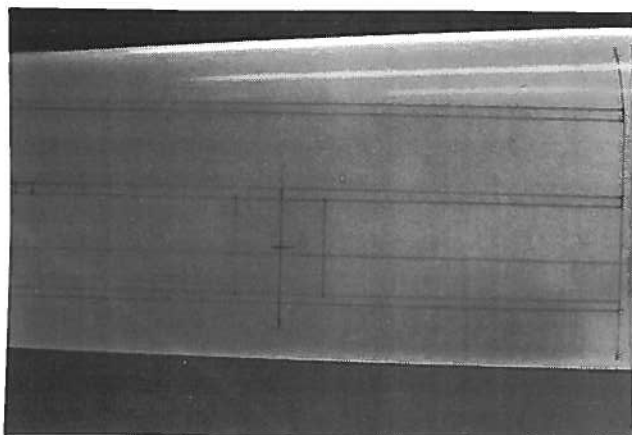
13.51. Note the locations of the stringers and bulkheads as they are drawn on the sides of the fuselage.

## FUSELAGE BULKHEADS AND STRINGERS

The fiberglass fuselage is reinforced with a number of internal bulkheads and stringers. These elements add rigidity and strength to an otherwise weak and flexible fuselage. It is very important that you install all the bulkheads, reinforcement pieces and stringers.

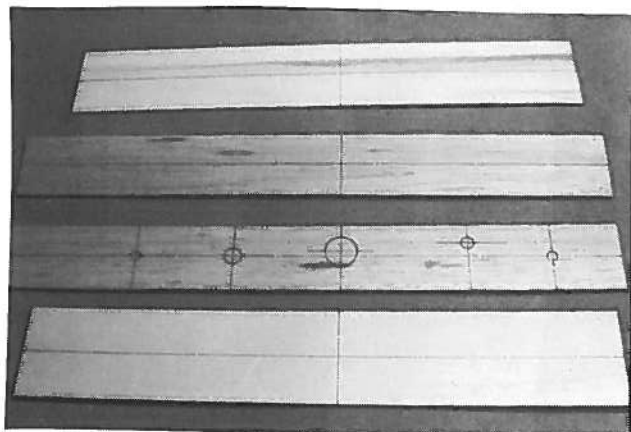
13.48. Study the marks on the sides of the fuselage and the plans.

13.49. Photocopy the bulkheads onto a piece of paper. Cut them out and paste them onto 1/8" piece of light plywood.



Guide Lines For Bulkheads On The Sides Of The Fuselage

**13.52.** Fabricate the root ribs for the wings. Lay out and draw the centerlines and required holes on the root ribs.



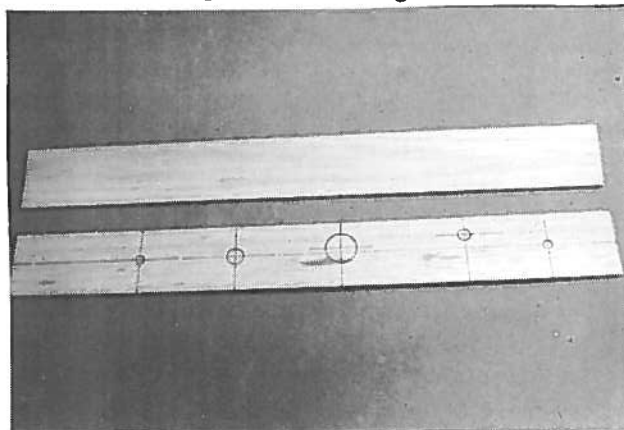
Root Ribs and Fuselage Side Supports With Hole Layouts

The large flat Prophecy fuselage sides are prone to have some very slight waves. Because of the flexible sides, even when the  $\frac{1}{4}$ " square formers are in place, it is extremely difficult to fit the root rib to the fuselage and have it fit tightly.

Therefore, we have added what we call fuselage side supports. These side supports are strictly an option. They do add a little weight to the airplane. They make the root rib fitting to the fuselage much easier and offer more attachment area for installing servo trays and anti-rotation pins.

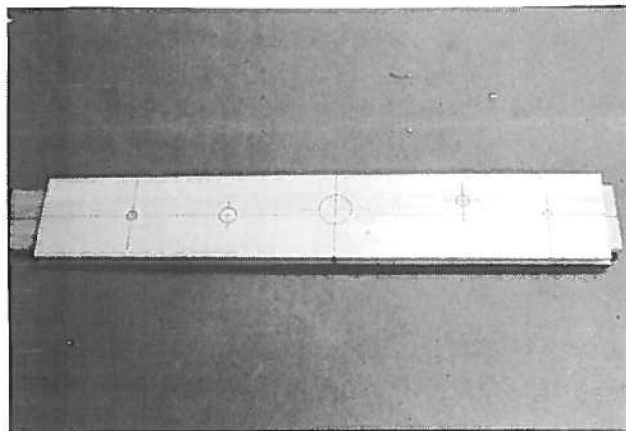
**13.53.** Fabricate the fuselage side supports just a little bit longer than the distance between the

two main fuselage bulkheads and as wide as the two  $\frac{1}{4}$ " stringers. Lay out and draw the hole locations on the side supports for the anti-rotation pins, servo wire leads, landing gear retract actuating rods and wing tube.



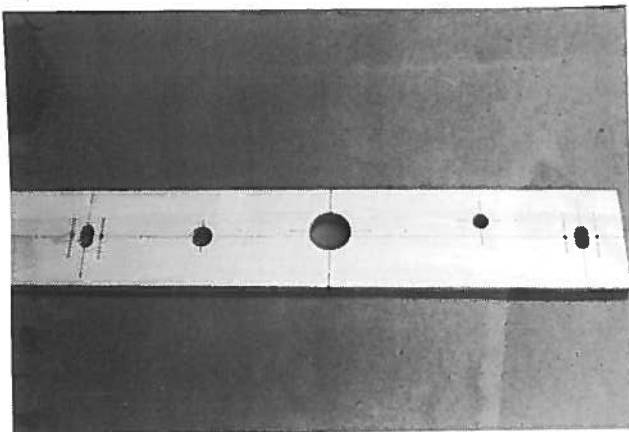
Hole Locations Drawn On The Side Supports

**13.54.** Sandwich and align the root ribs between the two fuselage side supports. Align the centerlines of all four pieces and tack glue them together.



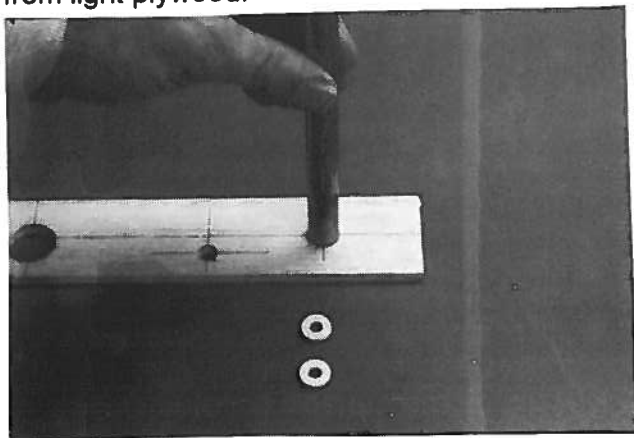
Root Ribs and Fuselage Side Supports Aligned and Tack Glued

**13.55.** Cut out the holes in both the root ribs and fuselage side supports for the anti-rotation pins, wing tube, servo wire lead and landing gear retract actuating rod.

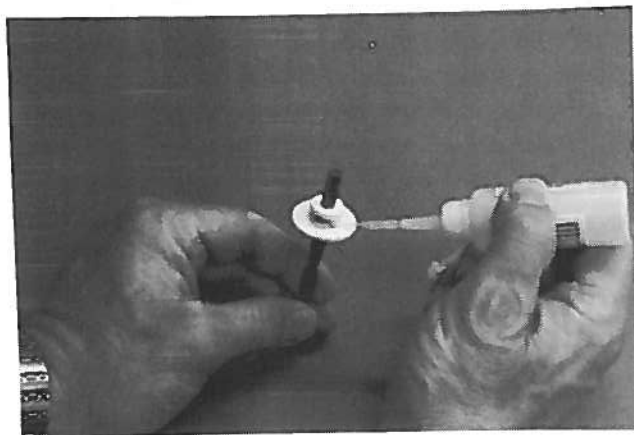


Required Holes In The Fuselage Side Supports

**13.56.** We reinforce the anti-rotation pin locations in the root ribs. We believe that the balsa root rib is a little weak to support the possible flying imposed loads that might be imparted via the anti-rotation pins. Cut  $\frac{3}{4}$ " diameter holes in the root rib balsa with a sharpened brass tube. Choose a hole saw that has an inside diameter of  $\frac{3}{4}$ ". Hole saw  $\frac{3}{4}$ " disks from light plywood.

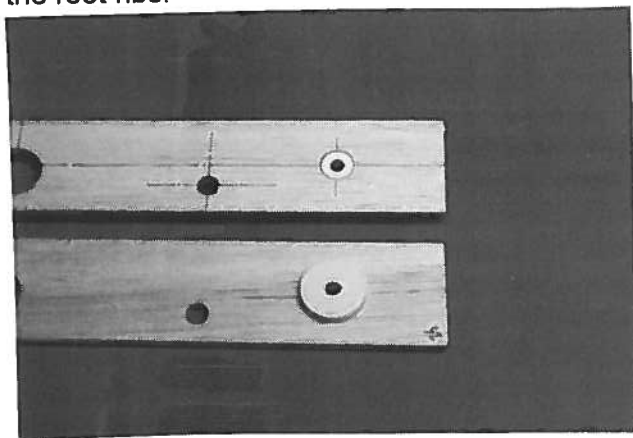
 $\frac{3}{4}$ " Holes Cut For Anti-Rotation Pin Reinforcements

**13.57.** Hole saw disks that are approximately 1- $\frac{1}{4}$ " in diameter. Using a  $\frac{1}{4}$ " diameter drill for alignment, place the  $\frac{3}{4}$ " disk over the 1- $\frac{1}{4}$ " disk and glue them together. Make four of these assemblies.



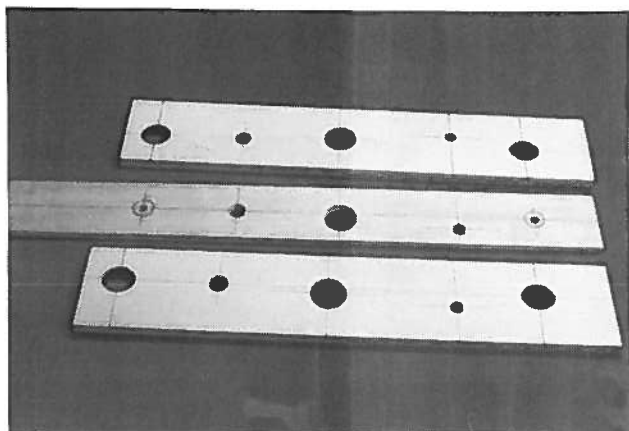
Anti-Rotation Pin Reinforcements

**13.58.** Glue the reinforcement assemblies into the root ribs.



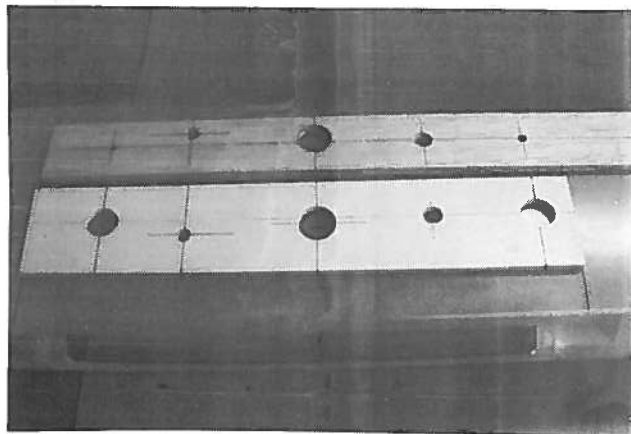
Reinforcements Glued Into Root Ribs

**13.59.** Remember, there is a right and left root rib. Put the reinforcements towards the wing side of each root rib.



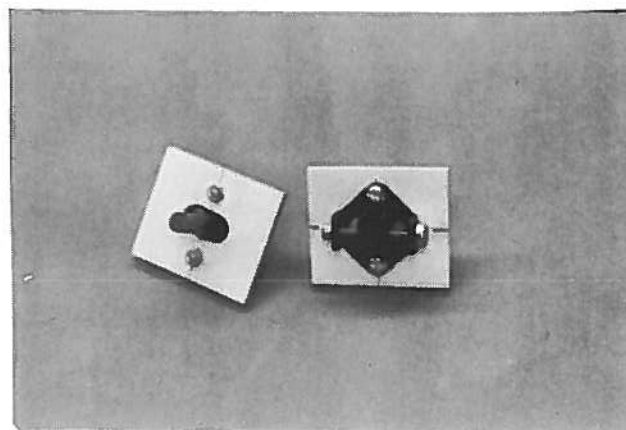
Anti-Rotation Pin Reinforcements Installed In Right/ Left Root Ribs

**13.60.** Lay the fuselage side supports and root ribs on a side of the fuselage. Align the centerlines and check to ensure all holes are aligned in their correct positions. Set aside the root ribs for now.



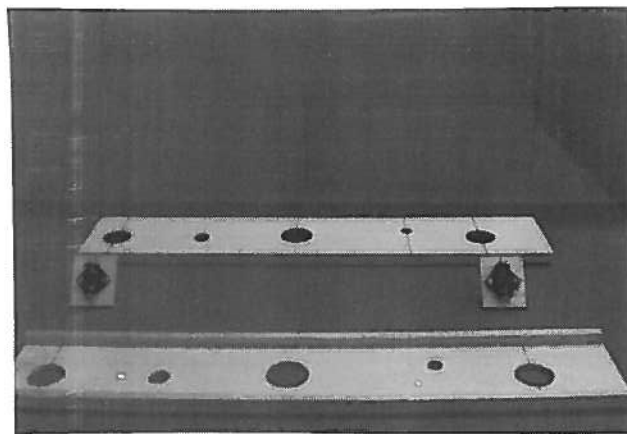
Fuselage Side Supports and Root Ribs On Side Of Fuselage

**13.61.** Fabricate four plates to support the anti-rotation pins. Note the slots for adjustments. Bolt the adjustable anti-rotation pins to the plates.



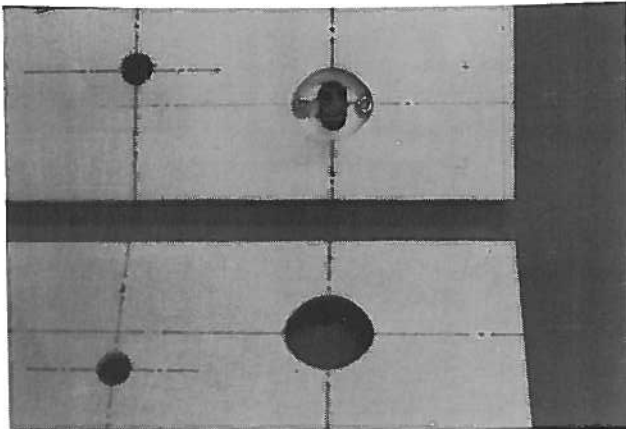
Adjustable Anti-Rotation Pins Bolted To Plates

**13.62.** Glue 1/4" stringers to the fuselage side supports. Again, remember there is a left and right fuselage side support. Check everything again to ensure the fuselage side supports and the fuselage marks all are aligned.



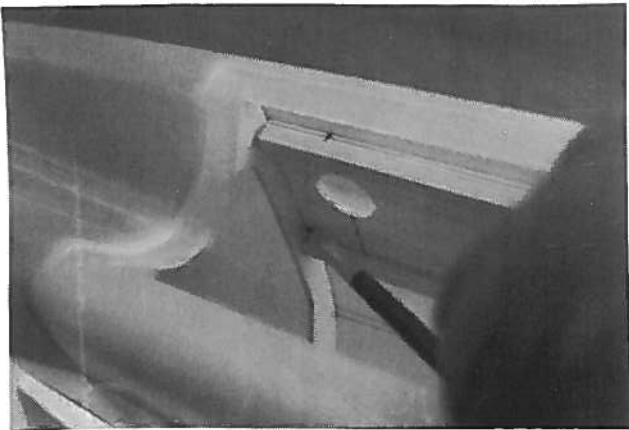
Fuselage Supports, Fuselage Marks, And Anti-Rotation Pins Aligned

**13.63.** Enlarge the holes in the fuselage side supports to accommodate the anti-rotation pins and the fastening bolts. This serves two purposes. It countersinks the assembly so you don't have to bolt the anti-rotation pins through the fuselage sides. Also, anti-rotation pins can be removed in the future if one should happen to wear out or break.



Anti-Rotation Pin Fitted To Fuselage Side Support

**13.64.** Dry fit the bulkheads, stringers and fuselage side supports inside the fuselage. Mark the location of the fuselage side supports on the bulkheads.



Formers And Fuselage Side Supports Dry Fitted For Fit

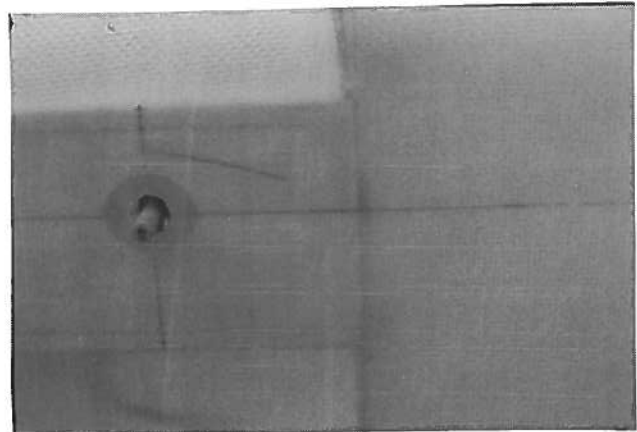
**13.65.** Remove the bulkheads and remove the excess material. Again dry fit the bulkheads and fuselage side supports. The bulkheads should slide over and support the ends of the fuselage side supports and stringers.

**13.66.** Fit all the bulkheads and fuselage side supports inside the fuselage. Align all the pieces with the marks on the outside of the fuselage. Once satisfied that everything fits and is correctly aligned, glue all the components in place. Note, the anti-rotation pins and plates aren't attached at this time. This step will happen later.



Fuselage Side Supports And Bulkheads Glued In Place

**13.67.** Drill two holes through each side of the fuselage to accommodate the anti-rotation pins. Make the holes just a little larger than the pins themselves.

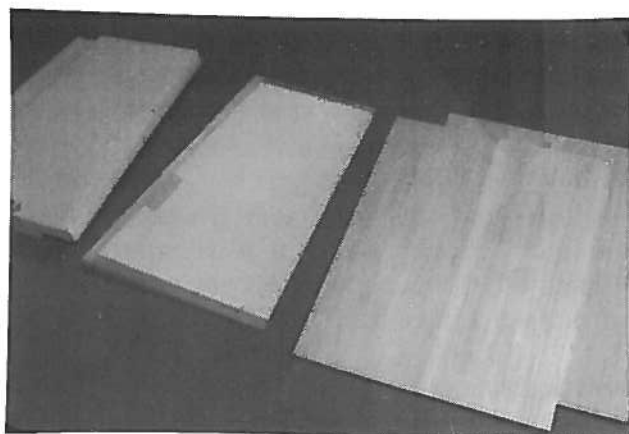


Enlarged Hole In Fuselage For Anti-Rotation Pin

## RUDDER CONSTRUCTION

**13.68.** Cut the required-size balsa sticks for the hinge post, bottom and top rib. Cut the bottom rib with enough excess to allow for shaping. The bottom rib will be shaped to blend into the fuselage.

**13.69.** Glue the bottom and top rib and hinge post to the foam core.



Facing On Rudder

**13.70.** Drill a hole for the 3/8" dowel for the rudder control horn with a piece of sharpened brass tube. Install a piece of 3/8" dowel by first sliding it into the hole in the foam core and then tracing the outline of the adjacent foam area on the dowel. Cut the hardwood dowel and glue it in place. Sand the hardwood dowel flush with the adjacent foam. Be careful and take your time. See instruction 4.3, page 20 for a graphic picture.

**13.71.** If you wish to experiment with honeycombing, the rudder is a good place to start. Before you install sheeting, draw a "honeycomb" pattern on the core. We leave at least a 1/2" border around the edges; our rudder holes are then about 1" square with 1/4" strips of foam. See instruction 4.8, page 21 for a graphic picture.

**13.72.** Cut out the "holes" with a sharp X-Acto knife. Apply epoxy to only the foam area, with either a monojet syringe or an acid brush. For a further explanation on how to apply the epoxy, refer to the sheeting section in the wing/stab section.

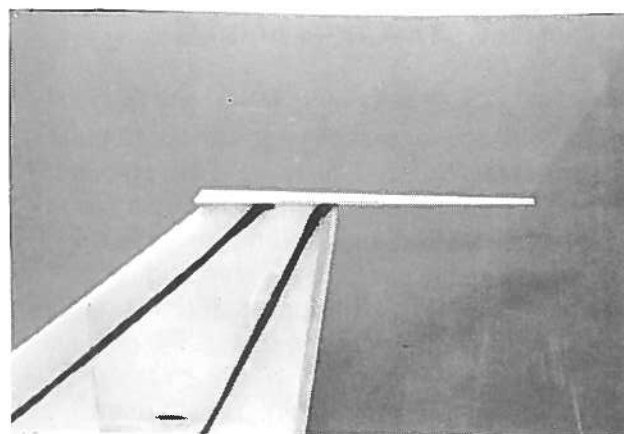
**13.73.** Sheet the rudder with 1/16" balsa. Read the instructions on sheeting in the "Wing & Stabilizer Sheeting" section, page 35 if you wish to honeycomb your rudder.

**13.74.** Using an X-Acto knife or a razor blade, slice 1/4" off the rudder core trailing edge. Glue a piece of 1/4" square balsa on the trailing edge using Tite-bond or epoxy. When dry, shape the trailing edge using a razor plane and sanding block. Bevel the leading edge to allow at least 45° travel in each direction.

**13.75.** Drill the dowel for a control horn bolt size of your choice.

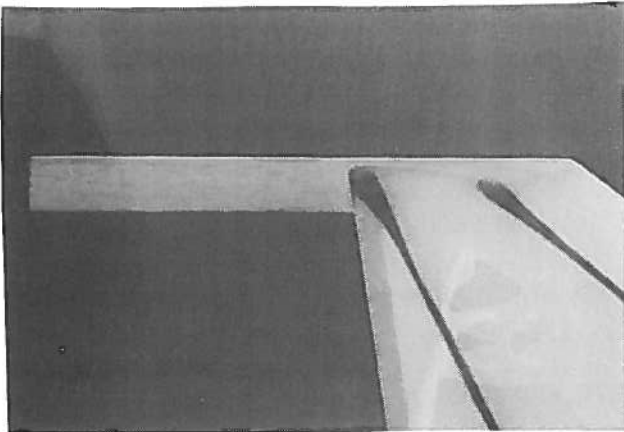
**13.76.** Cut slots for hinges in the fuselage rudder post and rudder hinge post. Put the rudder assembly aside for now. The tail post and rudder will not be installed into the fuselage until after the horizontal stabilizer has been installed.

**13.77.** As per the plans, fabricate the vertical stabilizer extension. Start the construction by fitting a 1/8" piece of light ply to the top of the vertical stabilizer.



Vertical Stabilizer Extension Glued To Vertical Stabilizer

**13.78.** Glue a piece of 3/4" balsa wood under the extension as shown on the plans. Shape and sand the balsa wood to conform to the extension piece.



Vertical Stabilizer Extension w/ Filler Piece

**13.79.** Cut a piece of balsa filler and fit it to the vertical stab and the 1/8" light ply piece. Once sanded to conform to the airfoil of the vertical stabilizer, brush on thinned epoxy (thin it with alcohol) to the wood assembly. Lightly sand, and the vertical stabilizer extension is complete.

#### HORIZONTAL STAB: REMOVABLE

The advantage of this unit is the ability to remove the stab for shipping or transportation. Adjustment is seldom necessary if the stab is built and installed correctly. If you don't travel long distances with your airplane, or have no need to crate your airplane for shipping, you may decide the six-plus hours to add this option to your airplane isn't worth it.

The Prophecy stabilizer is thin. This causes some problems incorporating a removable stabilizer configuration. The EPS foam used for the foam cores can't be "point loaded." Any load on the foam from the tubes must be spread over as large an area as possible. Otherwise the tubes and their housings will become loose, allowing the stabilizer to move. Consequently, the airplane won't fly consistently. There isn't much EPS foam around the two tubes used for the removable stab feature because of the thin airfoil. Therefore, the foam areas around the two tubes must be reinforced for the longevity of the horizontal stabilizer. Vibration during flying will eventually destroy the foam adjacent to the

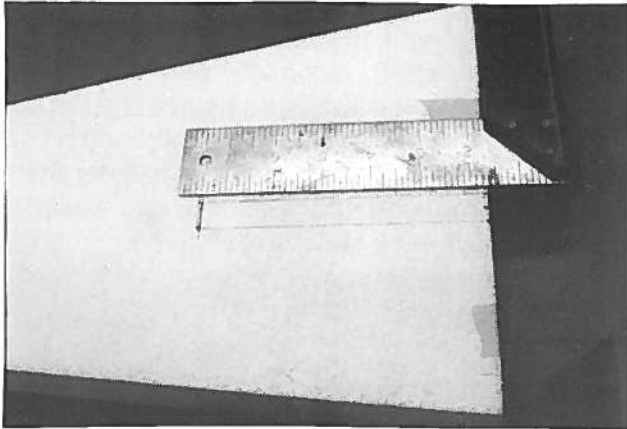
tubes and the stabilizer becomes loose. This happens over many (a minimum of one hundred) flights. You don't immediately notice degradation in the flying performance of your airplane if the stabilizer is loose. If you don't know the symptoms of a loose stabilizer it will drive you crazy trying to find the problem. Once you have a loose stabilizer it's no fun to fix. Therefore, reinforce the tubes during the initial construction and you won't have trouble in the future.

There are also two tubes to be installed in the stabilizer. These tubes must be installed parallel to each other both vertically and horizontally if you are going to have any chance of being able to join them. If they aren't exactly parallel, the pieces will bind when you try to join them as a unit. Consequently, we have developed a construction technique that ensures strength and rigidity even with the thin stabilizer. It also allows you to easily install the two tubes parallel to each other.

**13.80.** Trace the root of the stab core (the airfoil) on a piece of scrap 1/16" balsa wood. Cut out the airfoil from the scrap and set it to the side. See instruction 6.29, page 48 for a graphic picture.

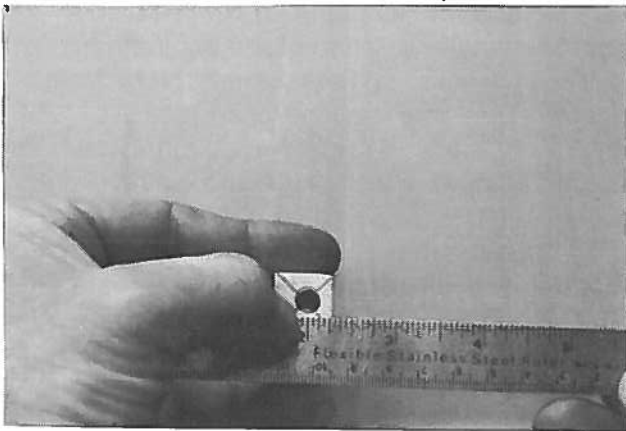
**13.81.** Cut the carbon fiber inner and outer tubes to the lengths shown on the plans. Separate the inner and outer tubes. Set the inner tubes to the side and only imbed the outer tubes into the stabilizer as noted in the following steps.

**13.82.** Using a builder's square, lay out the centerline locations of the carbon fiber rods and tubes on the stabilizer cores. Draw a line 1/4" offset towards the leading edge and parallel to the stab centerline. Draw another line 1/4" offset towards the trailing edge and parallel to the stab centerline. This will create an area that is 1/2" wide centered on the stab centerline. This area will be removed for the tubes and balsa backing.



Stab Half With Tube Assembly Layout Located

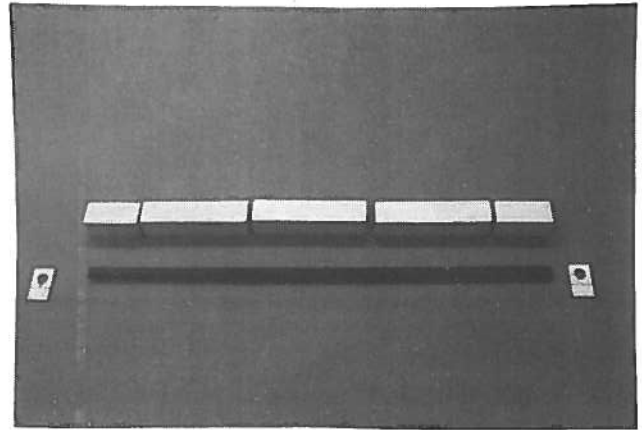
**13.83.** Cut one inch square by three-inch long balsa blocks. Use these blocks to reinforce the thin stabilizer where the carbon fiber tubes are located. On the end of each piece mark the center. Using a drill bit the same diameter as the carbon fiber tube drill a hole through the balsa blocks from one end to the other. Try to center the hole in the block as much as possible.



End View Of The Filler Block

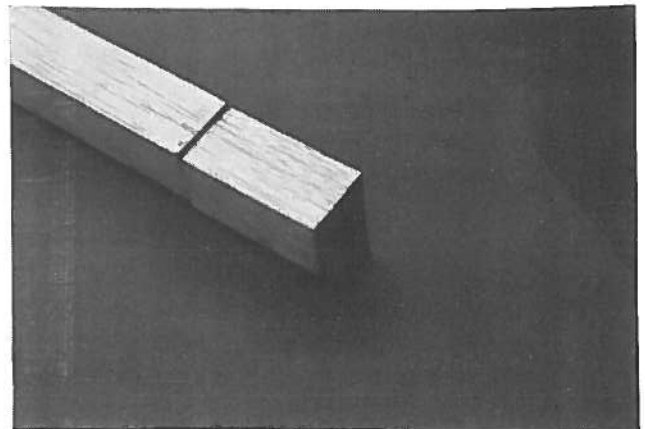
**13.84.** Construct four tube end supports from 1/32" plywood. These ends will support the tube ends at the same height above the working surface to ensure the tubes are "vertically" parallel. They should be approximately 1/2" x 1" long. Place one stabilizer half into its bottom shuck. Measure from the bottom of the shuck to the centerline of the stabilizer half. Transfer that measurement onto the tube end supports. Measure from the bottom of the support up and

draw a centerline. Drill a hole the same size as the carbon fiber tube on this centerline. Do this for the other three tube end supports. All the supports should be dimensionally identical.



Tube Reinforcement Pieces And End Supports

**13.85.** Dry fit all the reinforcement pieces onto the tubes. They probably won't mate up very well. This is acceptable. The pieces should cover the tubes except for the last 1/16" of the tubes. Once satisfied with the length and fit, using epoxy, glue the reinforcement pieces and end supports onto the tube. Make sure the end support bases are parallel to each other. Do this by holding the ends and pressing the support bases onto a flat surface.



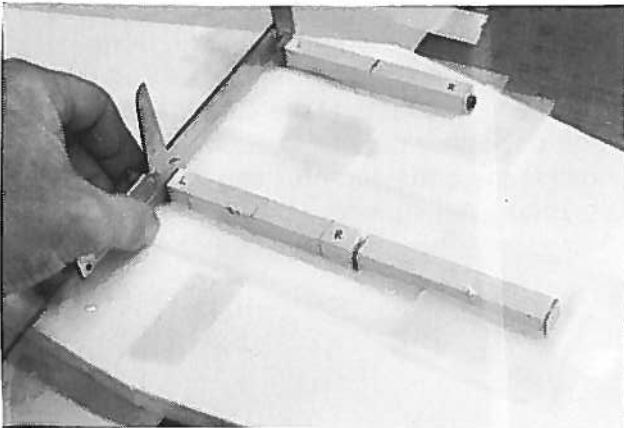
Tube Reinforcement Pieces And End Supports Glued In Place

**13.86.** Sand the balsa reinforcement piece sides even with the end supports. Once you have completed this step you will have two tubes with reinforcement pieces and end supports that are

approximately  $\frac{1}{2}$ " x  $\frac{1}{2}$ " and when placed on a flat surface are "vertically" parallel to each other.

**13.87.** Place the stab cores in the shucks. Tape the shucks together using masking tape. Tape the two stab halves together. Cut out the two  $\frac{1}{2}$ " wide areas from both the stabilizer halves and the shucks. Remove the cores and dry fit the two tube units into the appropriate slots in the shucks. Check the distance between the two tubes so they are exactly the same distance apart. Remove foam from the shucks as necessary.

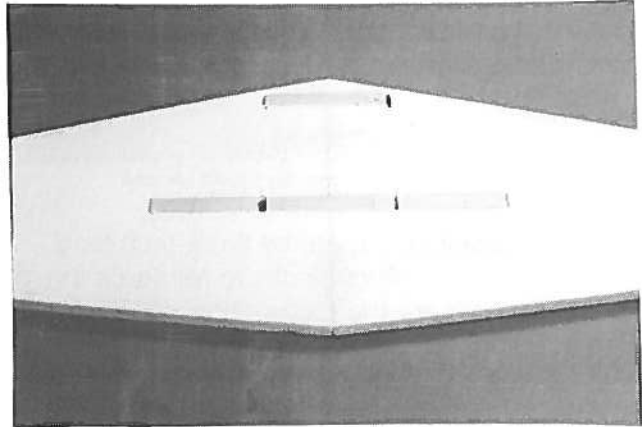
Look carefully at the photo below. Notice that we have cut two narrow grooves into the reinforcement pieces in the longer tube the same distance apart as the length of the smaller tube. These grooves are also centered on the longer tube. By doing this we are measuring the distance between the tubes only. This step ensures that the two tubes are exactly parallel.



Tubes Dry Fitted Into The Shuck Slots And Dimensions Checked

**13.88.** Once satisfied with how the tube assemblies fit into the shucks, dry fit the cores over the assemblies and check the fit again. Remove foam if necessary to ensure the two tube assemblies are still parallel. When everything fits properly, remove the cores and place waxed paper around the perimeters of the tubes and on the shucks. This will keep the epoxy from gluing the cores to the shucks. Apply epoxy to the balsa on the tube units and slide the cores over the tubes onto the shucks. Make

sure the shucks are resting on a very flat surface. Again check the tube assemblies to ensure they are still "horizontally" parallel. Place waxed paper over the tubes and place the upper shuck on top of the cores. Place a flat board over the assembly and lightly weight it. After the epoxy has cured remove the shucks and waxed paper. You now have two parallel tubes.



Cores With Tubes Installed

**13.89.** Refer to the kit plans. You will notice a "balsa filler" at the location of the control horn. The balsa filler is used to distribute forces from the control horn into the control surface. To install this balsa filler, remove the foam core material as noted on the plans and, using carpenter's glue, glue a piece of balsa (the size of the material removed) in the void. Once dry, sand the balsa filler to the shape of the foam core. Note: This is extremely important when a 4-cycle engine is used; the vibration caused by the engine will destroy the mounting area around the elevator and aileron control horns. This balsa filler, in conjunction with a hardwood dowel, will ensure that the vibration will not affect the control horn mounting area.

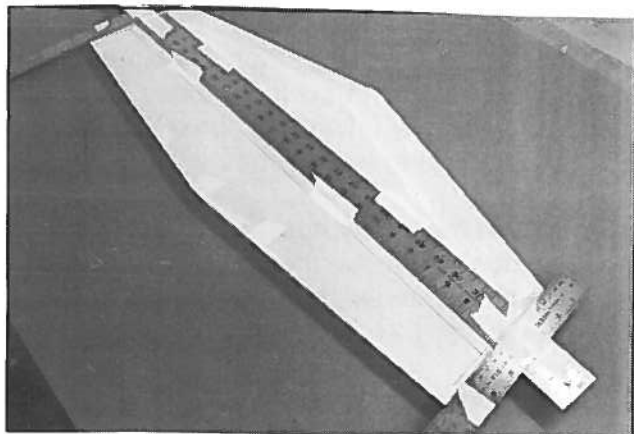
**13.90.** Sheet the two horizontal stab halves.

**13.91.** Install the leading and trailing edges.

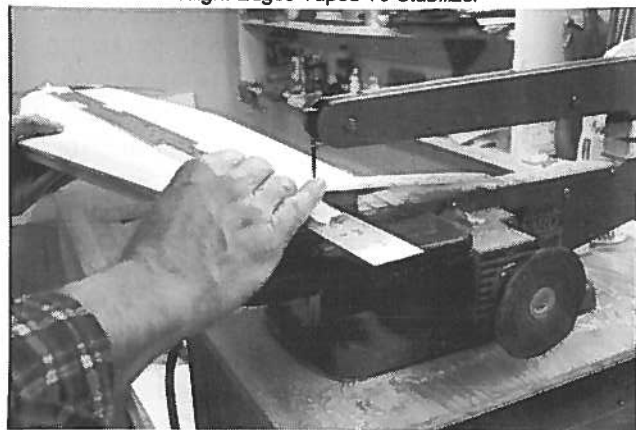
**13.92.** Install the stabilizer tips.

**13.93.** Using a fine line marker, draw the locations of the elevators on the horizontal stabilizer.

**13.94.** Cut the elevators from the horizontal stabilizer. Place and tape the stabilizer on the lower shuck. This next little tip is worth the price of this book! *To cut this line absolutely straight, tape a metal straight edge onto the stab and the edge over the elevator cutout line. Place the stab and shuck on the Dremmel saw and lightly apply pressure against the metal straight edge and cut along the line.* The cut is as straight as the metal straight edge you use. You can also use this method to cut out the ailerons out of the wings.



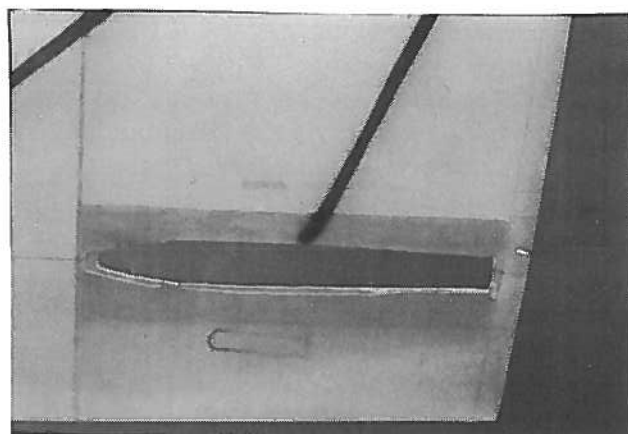
Straight Edges Taped To Stabilizer



Cutting Out Elevators With Metal Straight Edges

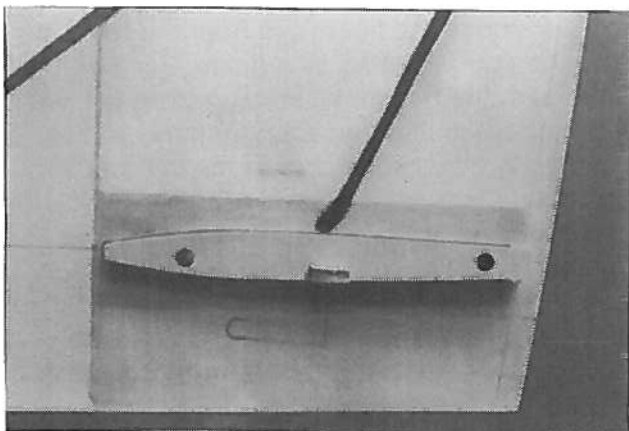
**13.95.** Face the raw edges of the horizontal stabilizer and elevator.

**13.96.** Remove the fiberglass from the fuselage using the outline marks as a guide. For fuselage supports at the horizontal stab opening cut two pieces of 1/8" balsa that span from the vertical bulkhead in front of the stab to the tail post. Dry fit the two pieces inside the fuselage to check for proper fit. Once satisfied with the fit, glue the supports in place. Trim out the excess balsa to the outline of the stab airfoil in the fuselage. The extra balsa pieces add rigidity, strength and gluing area to the joint between the fuselage and the stab.



Balsa Filler Inside Fuselage Around Horizontal Stab Opening

**13.97.** Slide the stab into the hole in the fuselage. Strive for a gap of approximately 1/32" to 1/16" between the fuselage and the horizontal stabilizer all the way around the opening. If there is any binding, the final stab alignment will be off. Note: for clarity we have jumped a few steps ahead and have shown only the middle section of the horizontal stabilizer.



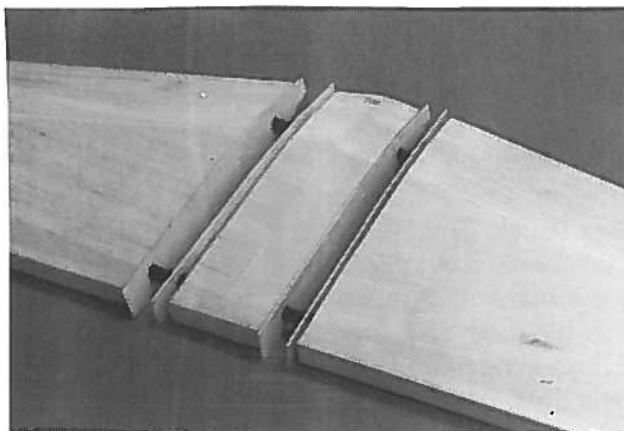
Checking Horizontal Stab Clearance With The Fuselage

**13.98.** Align the stab with the fuselage. Use the triangulation method previously described in step 6.22. Once you've established the alignment, mark the sides of the fuselage on the stab.

**13.99.** Remove the stab from the fuselage. Draw a fillet line parallel to it, towards the tip and approximately 3/8" from the established fuselage side line.

**13.100.** Cut the stab, including the carbon fiber outer tube now located inside the stabilizer, into three pieces along the fillet lines. Use the method we described previously, with the metal straight edge, to cut these lines absolutely straight.

**13.101.** Cut two 1/32" bass wood root ribs. Allow approximately 1/8" of extra material around the edge. Draw the location of the carbon fiber inner tubes on the root rib. Cut a hole for the carbon fiber inner tube in the root rib. Slide the root rib over the carbon fiber inner tubes. Then slide the carbon fiber inner tubes into the stab halves and middle section. Trace the stab root airfoil on the root rib. Remove the root ribs and remove most of the extra material from the root ribs.



Stab Root Ribs Dry Fitted In Place

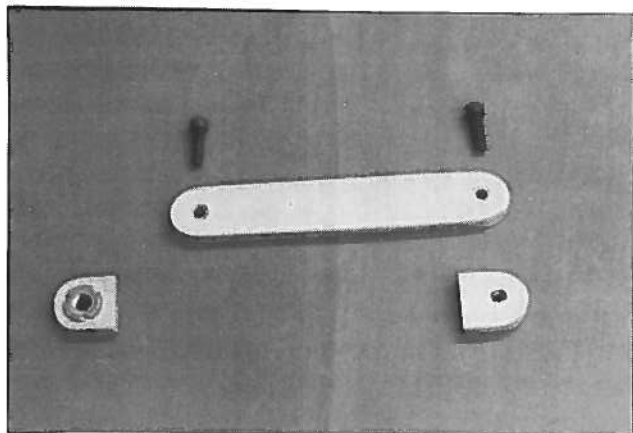
**13.102.** Tack glue the mating root ribs together. Glue the pairs of root ribs to the stab halves and middle section with epoxy. Before doing this, clean the carbon fiber inner tube and apply a coat of good car wax to the inner tubes. The car wax will prevent any unwanted epoxy from permanently sticking to the tubes.

**13.103.** Once the epoxy has cured, split the pieces apart and remove the carbon fiber inner tube. Sand the root ribs to match the horizontal stabilizer airfoils.

**13.104.** Note that the instructions for the Prophecy shows an aluminum tube used for anchoring the stab halves to the fuselage. If done correctly this tube must be parallel to the other two. If you're adventuresome go ahead and build the mounting system noted in the plans. We have come up with another anchoring device that eliminates the need to try and align a third aluminum tube to the other two carbon fiber tubes. *You might consider the simplicity of this alternate attachment device.*

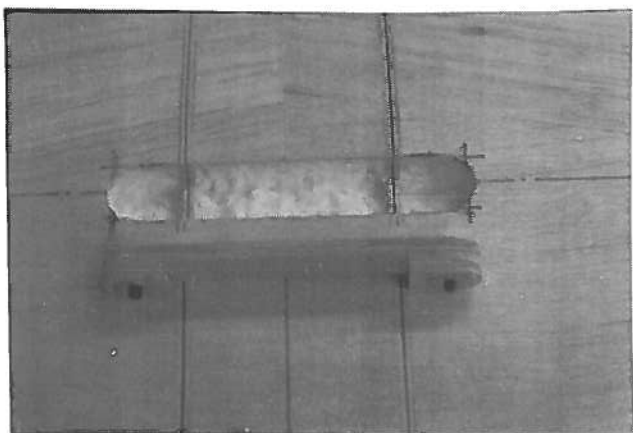
**13.105.** This anchoring device consists of three pieces. The middle piece spans across the middle stabilizer section and binds the two stabilizer halves together. There are two small plates that mount in the stabilizer halves and a piece that mounts into the middle section. Proportion the dimensions to your own liking.

The width of the assembly is  $\frac{1}{2}$ ". Use 4-40 blind nuts on the two stabilizer tabs.



Stabilizer Fastening System Components

**13.106.** Once complete, lay the assembly across the middle stabilizer section. Mark the cutout area on the stabilizer for the attachment device. Remove material as necessary. Dry fit all the pieces both as a unit and separately until you obtain a nice fit. Fasten all the pieces together as a unit and epoxy the tabs to the stabilizer halves and the attachment piece to the stabilizer middle section. Try to avoid gluing any of the pieces together. When the epoxy has cured remove the 4-40 bolts and remove the stabilizer halves from the middle section.



Anchoring Device Aligned With Stabilizer Recess

**13.107.** The assembly device should be recessed into the stabilizer. Cut a piece of soft balsa wood the width of the attachment assembly. Choose a thickness for the filler piece

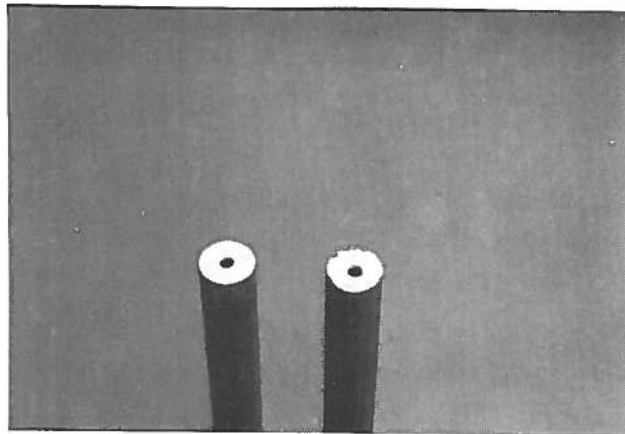
that allows it to extend above the adjacent surfaces. Glue the balsa piece onto the top of the attachment device. Drill a hole through the balsa filler. Remove balsa from around the holes to allow the 4-40 bolt to recess into the filler. Assemble the stabilizer and sand the filler smooth with the adjacent areas.

**13.108.** Assemble the stab halves and middle half together.

**13.109.** Slide the stab into the hole in the fuselage. Once the stab fits inside the fuselage hole, you're ready to install the stab and start the alignment process as outlined in the "Assembly" section.

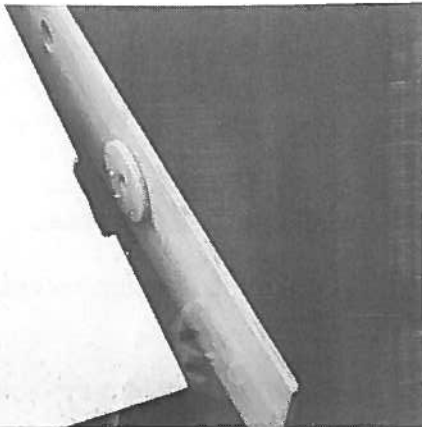
## WING CONSTRUCTION

**13.110.** Cut the phenolic wing tube into three pieces, two lengths equal for the wing halves and the remaining piece to be mounted in the fuselage as shown on the plans. On one end of each wing tube glue a  $\frac{1}{8}$ " light ply disk. Anchor this disc securely to the tube. The light ply disk will prevent the aluminum tube from sliding into the wing due to vibration.



Plywood Discs In Each End Of The Phenolic Wing Tubes

**13.111.** Retrieve the root ribs that were set to the side earlier. Slide a phenolic tube into each of the wing panels. Slide a root rib over each of the phenolic tubes. Remove foam from the wing core around the anti-rotation pins for clearance.



Foam Core and Anti-Rotation Pin Plates

**13.112.** Fit the false ribs (the plywood plate on the outboard end of the phenolic tube) to the wing by sliding the plate into the slot, and pushing a wing tube through the hole in the wing core in the hole of the false rib. With everything in place, trace along the foam, marking the false rib. Remove the rib and cut off the excess. Refit the rib to the wing core. Sand the excess off so the false rib exactly matches the contour of the wing core.

**13.113.** Cut out a recess for the aileron servo in each wing panel.

**13.114.** Cut tunnels for the aileron wires and the landing gear linkage or retract air lines by cutting the foam with an X-Acto knife. Remove the excess foam.

**13.115.** Prepare the fuselage for the phenolic tube by cutting holes in the fuselage approximately 1/16" diameter larger than the phenolic tube. This will allow for a *slight* amount of up, down, and side-to-side tube movement during the assembly process.

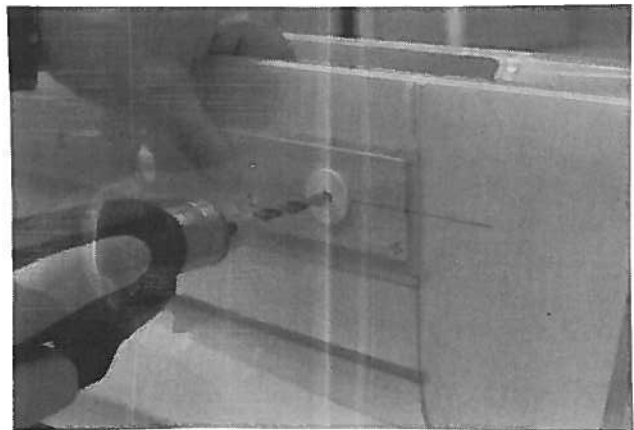
**13.116.** Assemble the phenolic tube and ply plate assembly for the inside of the fuselage. Trial-fit it into the fuselage. The assembly should fit tightly, but not bulge the sides of the fuselage. Do not glue this assembly into the fuselage until you perform the final assembly and alignment steps.

**13.117.** Temporarily install the phenolic tube and ply plate assembly in the fuselage. Slide the aluminum tube through the phenolic tube, centering the aluminum tube in the fuselage.

**13.118.** Slide the wing phenolic tubes on the aluminum tube and butt them against the side of the fuselage. Slide the root rib over the phenolic tube. Slide the wing cores over the phenolic tubes and against the root ribs. Triangulate measurements from the rear of the fuselage and align the wing so both measurements are *exact* (yes, tolerance is only 1/64"). Determine the required wing incidence angle from the plans. Using the thrust line drawn on the fuselage, align the root rib with the proper incidence with an incidence meter.

**13.119.** Once aligned, tack glue the root rib to the fuselage with a dab of *thick* CA glue. This step ensures the root of the wing matches the contour of the fuselage.

**13.120.** Once the root rib is secured to the fuselage, remove the wing cores, phenolic tube and aluminum tube, and drill a 1/4" hole in the fuselage at the anti-rotation pin locations using the root rib as a guide.



Drill Locations For Anti-Rotation Pins In Fuselage

**13.121.** Glue the phenolic tubes in the wing cores and attach the phenolic tube to the false ribs with slow-setting epoxy. NOTE: Mark the end of the wing cores and shucks, if the

manufacturer has not done it, so they can be mated the same way they were cut. Coat the wing phenolic tube with epoxy and then slide it halfway in, pull it out and turn it around and push it all the way in while twisting to distribute the epoxy. It is not necessary to slop the epoxy in the socket; use as little epoxy as possible. Remember, allow 1/8" of tube to protrude from the wing core to slide into the root rib hole that has been cut to receive the tube. See instruction 5.53, page 33 for a graphic picture.

**13.122.** Clean the aluminum tube and apply several coats of good car wax to prevent any epoxy from permanently sticking to the tube. NOTE: If something should happen to the aluminum wing tube, do *not* replace it with anything other than 6061 T-6 or 2024 T-3 grade aluminum. There is a vast difference in the strength of some aluminum alloys. Do *not* replace the tube with hardware store stock. This material is not suitable for our use and will buckle at very low wing loading. If this happens ... down comes da plen!

**13.123.** With the root rib still glued to the fuselage, carefully apply a slow-cure epoxy to the face of the root rib that will mate with the wing core. Be neat; do not slop epoxy on the fuselage or any other component except the root rib. It is best to do this procedure one wing at a time. If some epoxy sticks to the aluminum tube, you can twist the tube to break it loose. At this time you will slide one wing panel onto the aluminum tube to mate with a root rib that has the epoxy on it and slide the other wing panel on the aluminum tube to mate with the root rib that *has no epoxy on it*.

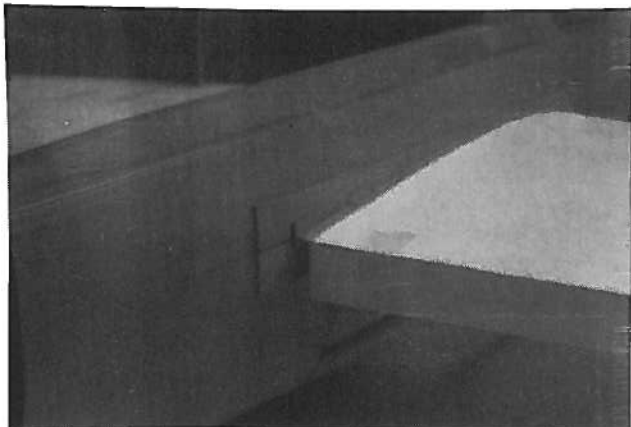
**13.124.** While the epoxy on the root rib is curing, check the alignment of the wings to the fuselage again. To make sure the wings are aligned horizontally, measure from the wing tips to the center of the rear of the fuselage. For vertical alignment, make sure the wing tips are the same distance from the work surface, and that the rudder post is perpendicular to the work surface.

To ensure that the rudder post is perpendicular to your work surface, use a builder's square. Hold one leg of the builder's square on the work surface and align the rudder post with the other leg of the builder's square. Place blocks or spacers under the wing tips to rotate the fuselage and align the rudder post properly. Take your time and get the alignment right, stand back and view the setup from a distance; you have plenty of time with slow cure epoxy.

**13.125.** Once the epoxy has cured, carefully cut the root rib that has been glued to the wing core from the fuselage and remove both wing panels from the fuselage. Do not remove the root rib that has not been epoxied to the wing core. Once all the components have been removed from the fuselage, and nothing remains glued together that is not supposed to be, slide the glued wing panel on the aluminum tube and epoxy the other root rib to the other wing core as noted previously. Remember to check the alignment again.

**13.126.** Once all the epoxy has cured, remove the wing panels from the fuselage and glue the anti-rotation pins to the root rib. The pins may be 1/4" brass tube, carbon fiber rod, or aluminum rod. Avoid using wood dowels, as they wear quickly.

**13.127.** Fill the gap between the root rib and the root of the wing core with a combination of epoxy and micro balloons. Remember to watch the weight! If necessary, slide balsa shims into any large gaps that exist between the foam cores and the root ribs.



Shim At The Trailing Edge Gap

**13.128.** If you choose to install a landing gear plywood plate, refer to the instructions and plans in the kit.

Epoxy the gear plates to the foam. Glue the balsa filler to the gear plate and sand to the contour of the wing in the immediate vicinity.

**13.129.** Harden the end of the phenolic tube at the root rib with thin CA glue. Apply a small amount of glue to the first 1/8" of tube, and lightly sand with 320 grit sand paper for a good fit with the tube. This step will make it easier to insert the aluminum tube, and prevent the phenolic tube from fraying.

**13.130.** Refer to the plans supplied with the kit. You will notice a "balsa filler" at the location of the control horn for the ailerons. The balsa filler is used to distribute forces from control horn into the control surface. To install this balsa filler, remove the foam core material as noted on the plans and, using Tite-bond, glue a piece of balsa the size of the material removed in the void. Once dry, sand the balsa filler to the shape of the foam core.

**13.131.** The wing cores are ready for balsa sheeting.

## SHEETING AND FACING THE WING

Prior to sheeting the wing, you should have installed:

- The outboard false rib
- Wing tube
- Root rib
- Balsa box for the aileron servo
- Triangular balsa block for the aileron control horn
- Landing gear box or plate
- A tunnel for the aileron servo control wire

We have explained how to install each of these items. Refer to the, "Sheeting and Facing the Wing and Stab."

## WING INSTALLATION AND ALIGNMENT

### JIG ALIGNMENT WITH A FLAT TABLE

If you want the most accurate alignment system for your airplane and you have access to power woodworking tools and an extremely flat surface, read further. NSRCA *K-Factor* editor, Eric Hawkinson, has improved on an old design of a jig alignment system. We have used this system on two airplanes and have had great success. The system consists of a set of wing and stab standards and an extremely flat surface.

### JIG CONSTRUCTION

Start by constructing the wing and stab support pieces. Study the pictures of the supports on the following pages while you read this description. Once or twice through and the construction will make sense.

We constructed our supports from maple. We wanted a hardwood because it is dimensionally more stable than softwood and hard and resists abuse. Absolute dimensions are not important in constructing the standards. However relative dimensions are extremely important. You are trying to construct a number

of identical supports. We started by cutting a block of wood approximately 3-1/4"x13" from "six-quarter" material. The approximate dimension of "six-quarter material is 1-1/4" thick. Make sure this block is as square as you can cut it. Next, cut a groove in the block using a 3/4" "V-groove" router bit approximately 1-1/4" from the bottom of the block. This is the most important cut of the operation. Done properly you will have identical standards. Done incorrectly and your airplane will never be aligned properly. Now cut the block into eight, 1-1/2" pieces. Drill a 1/4" diameter hole vertically through each support. Locate the hole approximately 7/16" from the rear of the support and slightly off-center. The "long" side of the support is used to support a carpenter's lever. Build the bases for each support from 1/4" all-thread rod and 3-1/2"x3/16"x1-1/2" soft wood. Use 1/4" wing nuts and washers to support the standards. Cut two pieces of 1/4"x1-1/2"x14" softwood. Cut a groove approximately 1/4" wide and approximately ten inches long. Permanently fasten each piece to the base of one standard. Install two "closet bolts" on two standards. Slide the attachment piece over the closet bolt and anchor it with a washer and wing nut. This mechanism is used to adjust the standards to the proper width and to hold them during the alignment phase. Repeat the process for the wing standards except make the base piece approximately twenty-four inches long and the groove approximately twenty inches long. You're done with the standards.

You ask, "Where can I get an extremely flat work surface?" We recommend a milled stone slab and suggest a couple of sources. Try the local billiard store. They might have pieces of chipped pool table slate that they would sell. Contact a local granite and marble countertop fabricator. They might have pieces that are either too narrow to use for countertops and islands that they will sell for a discount. Or, if you have the money, ask them to prepare a stone to the dimensions you wish. Another source might be the local grave stone supplier. You can build a support table out of plywood and dimension lumber. But incorporating an adjustable

alignment system into the table to allow for natural wood movement is the problem we have encountered in the past. Once you have obtained an absolutely flat surface and constructed the alignment jig, you are ready for the alignment process.

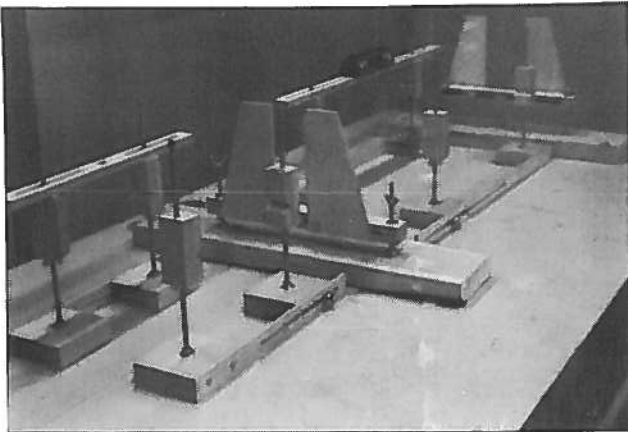
Establish a long straight line on the middle of your flat work surface. To do this on a stone surface, place a piece of masking tape down the middle of the length of the surface. Using a piece of string, stretch it between two points established in the middle of each end of the masking tape. Make marks on the masking tape at approximately one-foot intervals. Align a straight edge on the marks and draw a line. This will be used for the longitudinal alignment of the fuselage.

**13.132.** Temporarily install the rudder post in the back of the fuselage with masking tape. Using a Tetra hinging tool and a fine line marker, draw the centerline on the rudder post.

**13.133.** Enlarge the hole in the fuselage where the wing phenolic tube is located. This allows for up-and-down tube adjustment when the wing is leveled and squared to the fuselage.

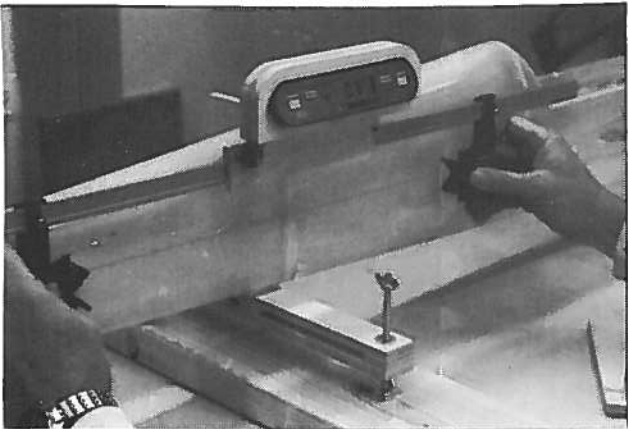
**13.134.** Establish all the centerlines on the fuselage.

**13.135.** Check to ensure that your flat surface is level. Set up the jig alignment system on the flat surface.



Jig Alignment System On The Flat Surface

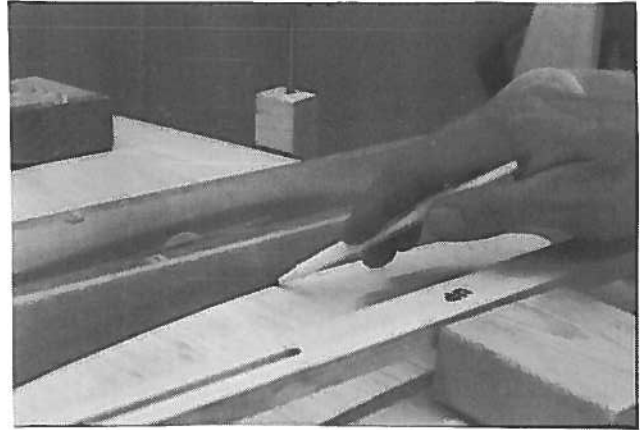
**13.136.** Place the fuselage into the fuselage jigs. Place one fuselage standard at approximately the firewall and the other three to four inches in front of the horizontal stab. Using either a level or an incidence meter, level the centerline of the fuselage. Adjust the fuselage standards by rotating the supporting wing nuts, either up or down, equally on each side of the standard as necessary.



Leveling The Fuselage In The Fuselage Jigs

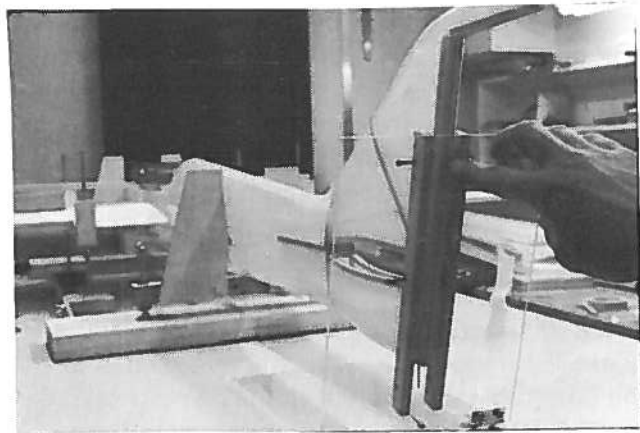
**13.137.** Insert the aluminum tube through the phenolic tube in the fuselage. The phenolic tube inside the fuselage shouldn't be glued in place at this time. Slide the wing panels onto the aluminum tube. Push the wing panel and aluminum tube against the side of the fuselage. Mark the top of the wing root location on the side of the fuselage with a fine line marker. Push the wing panel and aluminum tube against the side

of the fuselage. Mark the bottom of wing root location on the side of the fuselage with a fine line marker. These marks represent the limits of adjustment that are available during the alignment process.



Marking Top And Bottom Of Root Ribs On Fuselage Sides

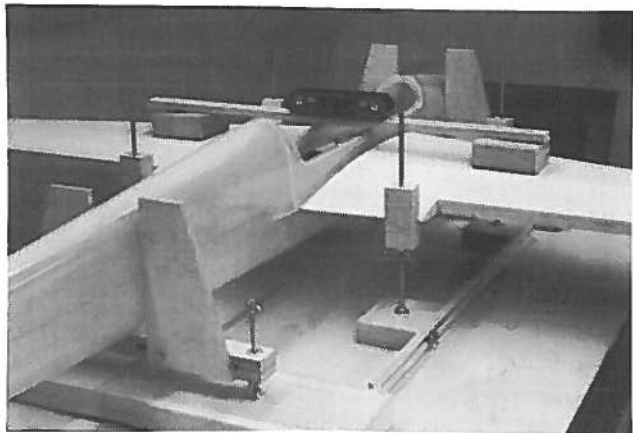
**13.138.** Attach a carpenter's square to the rudder post aligned with the centerline. This square will be used to ensure the vertical stabilizer is perpendicular to the working flat surface. We fabricated a device made of Plexiglas and hinges to replace the carpenter's square.



Vertical Fin Clamped In The Jig and Squared To Work Surface

**13.139.** Insert the aluminum tube through the phenolic tube in the fuselage (again, phenolic tube inside the fuselage shouldn't be glued in place). Slide the wing panels onto the aluminum tube. Expand a wing standard to its width limits and place it under a wing panel. Adjust the

height of the adjusting blocks so the grooves in the block are at the same level as the leading and trailing edges respectively. Close the standard so the adjusting block grooves engage the leading and trailing edges. Repeat the same process for the other wing panel. Place identical spacer blocks on the top of each wing panels over the aluminum tube at the same positions on each wing panel. Using a level or the incidence meter, level the wings. This will require you to rotate the adjusting block wing nuts on one wing panel up, and lower the adjusting block wing nuts on the other panel. Once the wing panels are level, check the fuselage centerline to ensure it is still level.

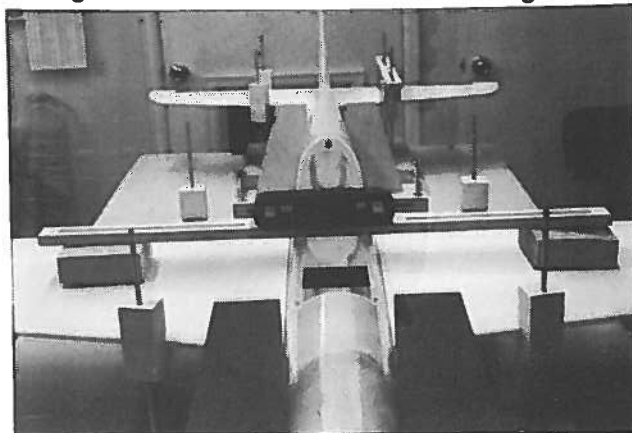


Wing Panels Levelled and In Adjusting Blocks

**13.140.** Check the vertical stabilizer carpenters square to ensure the vertical stabilizer is perpendicular to the flat work surface. If it isn't, rotate the fuselage. If the fuselage won't rotate to a perpendicular position, the fuselage phenolic tube is probably binding. Look at the fine lines on the fuselage. If the wing root is up against one of these lines then the wing panels need to be removed and the hole in the fuselage enlarged accordingly. Once you have enlarged the hole, erase the original fine line on the fuselage indicating the wing root limit, and re-establish the limit as previously noted. Enlarge this fuselage hole sparingly. This is a trial and error method. This hole shouldn't be too big. When there is appropriate clearance, there should be a small gap between the wing root and the fine lines on the fuselage. At this point

there is proper clearance and nothing is binding. It is extremely important that nothing binds. If an element is glued in a bounded position, once released from the jig the element will move and the aircraft alignment is useless.

**13.141.** With the wing level and perpendicular to the vertical axis of the rudder post, align the wing perpendicular to the horizontal axis of the fuselage, using the triangulation as shown below. For triangulation, we use a ruler and two pieces of piano wire. An old carpenter's tape cut to a workable length with a hole drilled in one end also works well. Drill a small hole, the size of the piano wire, at the rear of the fuselage and in front of the wing on the centerline of the fuselage. Glue the wire in the holes. Measure from the back of the fuselage to the wing tips. Adjust the wing back and forth until the lengths are within 1/64" of each other. This should be very easy if the wings were aligned properly during the root rib installation to the wing core.



Leveling, Squaring And Triangulating

**13.142.** The wing is now aligned both vertically and horizontally with the vertical stabilizer and the axis of the fuselage respectively. Tack glue the phenolic tube to the sides of the fuselage via the plywood reinforcing donuts around the phenolic tube. To check the alignment, remove the airplane from the jig, remove the wing panels and start the whole process over. If your measurements and alignment are consistent, permanently glue the phenolic tube to the sides

of the fuselage. This might sound like a lot of work, and it is, but alignment is critical.

**13.143.** It's time to set the incidence of the wing panels. Place the fuselage with the wing panels installed into the jig. Level the thrust line of the fuselage with the fuselage adjustment standards using either an electronic level or the Smarttool™ Incidence Meter as noted on page 193.

**13.144.** Place the incidence meter onto one of the wing panels. Adjust the incidence of the wing panel using the jig blocks by rotating it around the wing tube until you have obtained the correct angle. Tack glue the root rib to the fuselage. Slide the wing adjusters through the opening in the fuselage and into the small phenolic tubes in the wings. Check that the adjusters have sufficient clearance. Once satisfied with the fit, permanently glue the adjusters in place. Break the tack-glued bond between the fuselage and the root rib. Check the thrust line alignment and the wing incidence again. If the wing panel incidence is off, adjust it with the wing adjusters.

**13.145.** Place the fuselage with the wings installed into the jig. Insert the horizontal stabilizer in the fuselage hole. Using the horizontal stabilizer standards, position the horizontal stabilizer the same way the wings were positioned.

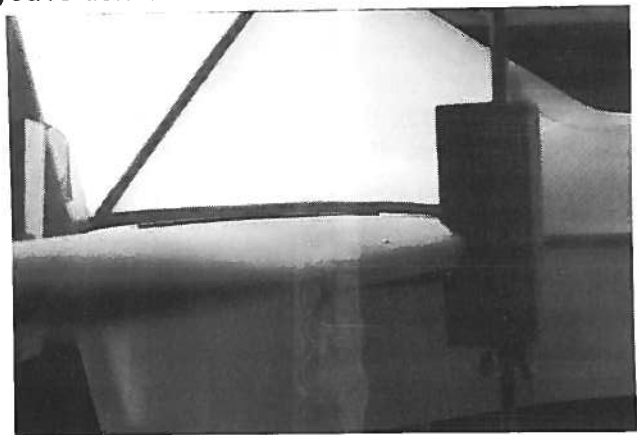
**13.146.** The horizontal stabilizer should be roughly parallel to the wing and perpendicular to the axis of the fuselage. Adjust the stab in the fuselage opening so the dimension from the fuselage to the corner of the elevator and stab tip are equal on both sides. Use a pin on each side of the horizontal stab to hold it in place.

**13.147.** Adjust the horizontal stab so the dimension from the wing tips to the horizontal stabilizer is the same. While you're adjusting the stabilizer, it will pivot around the two pins placed on the trailing edge of the horizontal stabilizer.

Once all the dimensions are established, place a pin in the leading edge next to the fuselage.

**13.148.** Adjust the incidence of the horizontal stab using an incidence meter or an electronic level and the adjusting blocks on the jig standards.

**13.149.** To ensure the horizontal stab is not binding against the fuselage, slide a piece of paper into the gap between the horizontal stab and the fuselage. Slide the paper around the opening. If the paper binds anywhere, mark the area on the fuselage. Remove the horizontal stab from the fuselage and remove a small amount of material from the fuselage to accommodate the piece of paper. Repeat the alignment process and check the gap. Once a piece of paper can be slid in the gap around the opening, you're ready to tack glue the stab in place. Once the stabilizer has been tack-glued in place, check alignment once again to ensure nothing has moved. If all is well, apply glue around each side of the stabilizer to firmly secure it permanently. Finish the stabilizer/fuselage junction by forming a nice fillet between the stab and fuselage using Evercoat body filler. Sand the fillet smooth and you're done.



Gap Between Fuselage and Horizontal Stabilizer

THE ALIGNMENT PROCESS OF THE WING, AND LATER THE STAB, ARE VERY IMPORTANT TO HOW YOUR AIRPLANE WILL FLY. THE IMPORTANCE OF PROPER ALIGNMENT CANNOT BE OVER-EMPHASIZED!

## RUDDER INSTALLATION

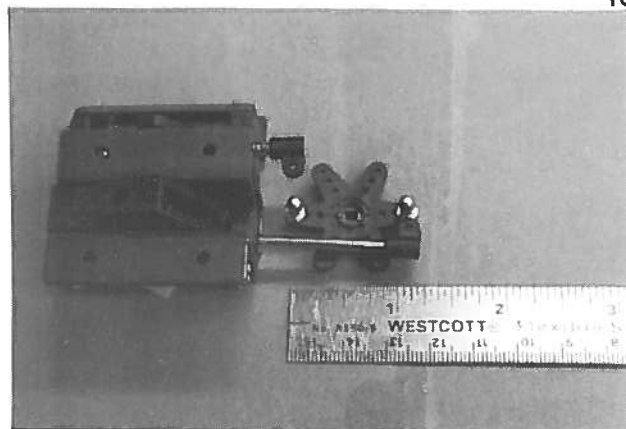
**13.150.** Epoxy the balsa tail post to the fuselage. Hold the assembly in place with strips of masking tape and cloth pins until the glue has cured. Remember to roughen and clean the fiberglass prior to applying the epoxy.

**13.151.** Temporarily hinge the rudder to the tail post and flare in the bottom of the rudder balsa skins and the lower rib to the fuselage with a sanding block.

## RETRACT LANDING GEAR INSTALLATION

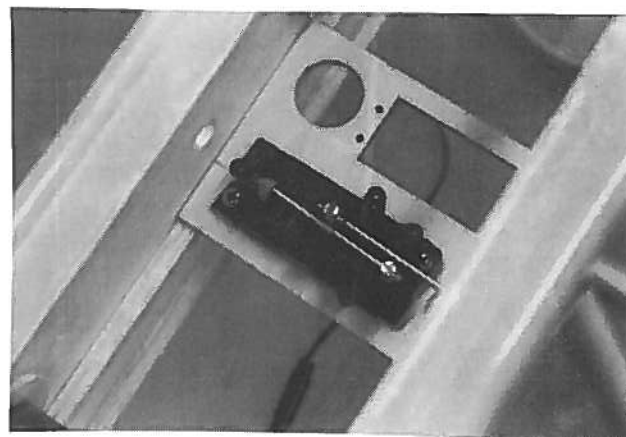
The retract landing gear installation for the Prophecy is unique. Typically, the retract landing gear system is accessed through a removable canopy on the top of the fuselage. However, the Prophecy's retract landing gear system is accessed through the bottom cover. The muffled pipe typically obstructs this cover and accessing the landing gear system is cumbersome every time you assemble the airplane. So a retract system was developed that could be assembled from the exterior of the fuselage without removing the bottom cover. It is a two-piece pushrod system with a keeper and a clevis. *Although it appears complex to build it is relatively simple.* Study the drawing included in the kit and follow our simple instructions and you shouldn't have any difficulty with this unique system.

**13.152.** Locate the retract servo so the center of the wheel is on the centerline of the fuselage. This ensures that each push rod assembly is equal in length. Fabricate the push rod assembly as shown on the plans. Attach the assembly to the servo wheel.



Servo Wheel Center Located On Fuselage Centerline w/ Pushrods

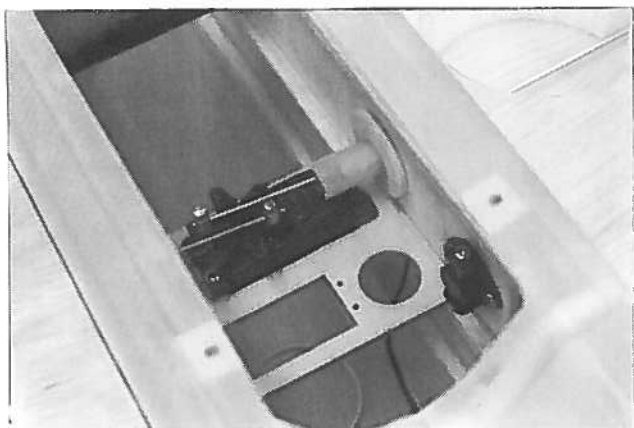
**13.153.** Measure the throw of your retract gear system. This is the amount of travel the retract gear actuating arm travels. Divide the retract gear throw dimension in half. Measure this distance from the center of the servo wheel out to the hole closest to this dimension. Install the retract servo fasteners in these holes.



Retract Gear Throws And Servo Wheel Dimensions

**13.154.** Fabricate all the components for the actuating arms as per the dimensions on the plans. You want the actuating arms inside the airplane to just protrude outside the fuselage with the servo in the "retract" position. Once the inside actuating arms are adjusted to the proper length, adjust the actuating arms attached to the retracts.

**13.155.** As per the plan, there are two vinyl guide tubes for the retract actuating arm articulating points. Note the vinyl tubes that are shown in the

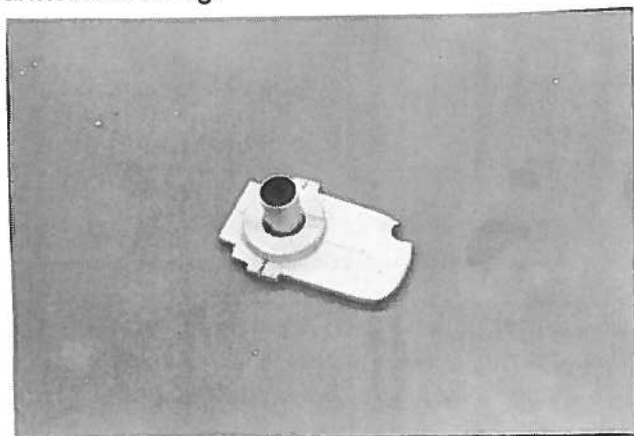


Retract Components Installed In Fuselage

**13.155.** As per the plan, there are two vinyl guide tubes for the retract actuating arm articulating points. Note the vinyl tubes that are shown in the picture below. These tubes are actually cut from Six Shooter Fuel Filler replacement tube from Dave Brown.

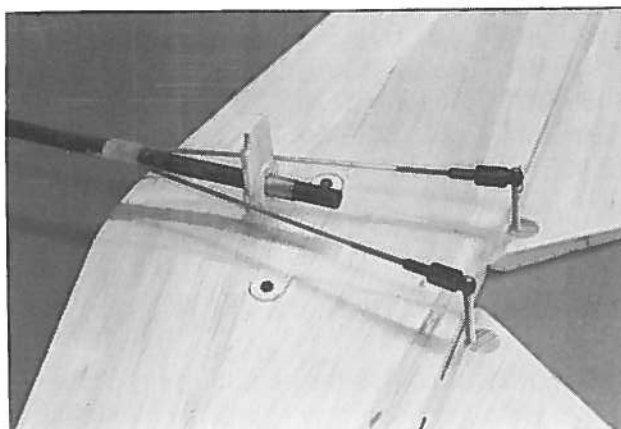
### ELEVATOR CONTROL LINKAGE

**13.156.** Fabricate the control rod bushing as shown on the plans. Note the notch on the edge of the former. This is a clearance cutout for the antenna housing.

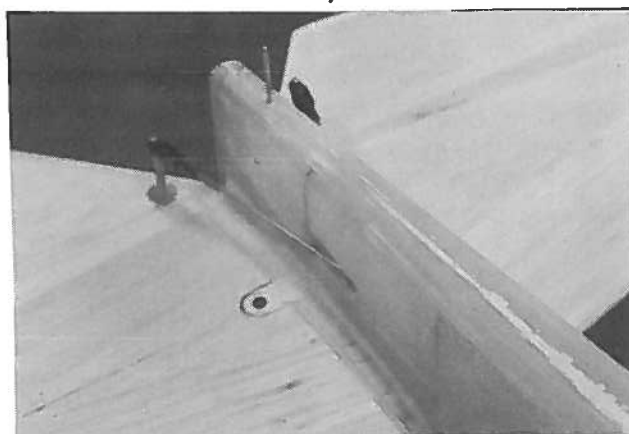


Rear Elevator Control Rod Bushing

**13.157.** Fabricate the elevator pushrod system as per the plans. The following picture gives you an idea of how this system looks inside the fuselage and how it connects to the elevator halves.



Elevator Pushrod System And Clevises



Elevator Pushrod System Installed In Airplane

### PIPE MOUNTING CLAMP

**13.158.** Refer to the drawings and plans for the pipe-mounting clamp. It is a simple Dave Brown plastic pipe mount installed on the bottom of the fuselage with a piece of silicone tube used as vibration control.



Rear Pipe Mount

## Chapter 14 THE RADIO SYSTEM

### GENERAL

The most important component in your airplane will be the radio. *If you've built the pattern airplane outlined in this book you'll have in excess of five hundred dollars of materials invested. This airplane is an incredible investment in both time and money. Don't compromise the whole project with an inexpensive radio.* There is nothing worse than watching your airplane head for terra firma because of a weak battery, poor connection, loss of signal, radio interference or a myriad of other possible problems. We only consider the top-of-the-line radios manufactured by either Futaba, JR, or Airtronics. These companies sponsor the top flyers and hang their names in front of everyone every time a top flyer takes off. They've put a considerable amount of time and money into the development of their equipment, and it shows. Take the time to learn each radio and choose one based on your own preferences. In our earlier years of pattern flying, we used an inexpensive radio. We paid dearly! When we sat down and thought about the time and money we'd lost, it was a foolish choice. *Obtain the best radio you can afford from the most reputable manufacturer.*

### RADIO SYSTEM HISTORY

Radios have not always been as reliable as they are today. In the early years of the hobby, radio systems were susceptible to both physical damage from vibration and interference due to the limited capabilities of the receiver's signal rejection. This questionable reliability and dependability was always in the back of an RC pilot's mind. He was constantly wondering if he would make it through the flight without radio failure.

The evolution of our radio systems throughout the years has been nothing short of phenomenal. Some of the first radios had rubber

band-powered "escapements." These were basically single channel operations. If you pressed the button once, the rudder would swing to the right. If you pressed the button twice, the rudder would swing to the left, after swinging momentarily to the right. They were electromechanical nightmares. The multi-channel radio, with actual servos, evolved next. The transmitters had self-centering lever switches for each channel. The switches were either "off" or "on." If you operated the switch, the servo was activated and it would swing the control surface to full throw. If you moved the switch to the right or left, you got full throw to the right or left respectively.

Then the modern proportional radio system was developed. "Proportional" means that if you move the transmitter sticks a small amount and hold that position, the servo will move a small amount and stay in that position. If you move the stick more, the servo moves a "proportional" amount more. Proportional radio systems were a dramatic step forward from the old lever switch or push button radio systems. Due to mechanical moving parts in the old reed receiver systems, you were required to orient the receiver in the airplane in a specific position to eliminate damage or interference from engine vibration.

Today, radio receivers are manufactured with electronic components only, which eliminated moving parts in the receiver and dramatically improved their reliability. In addition, the band widths on the frequencies of the older proportional radios were quite wide, so they were susceptible to radio interference. In 1988, the Federal Communications Commission (FCC) passed a rule that radio systems were required to meet narrow band "Gold Sticker" requirements by 1991. These requirements meant an increased number of frequencies, and a decreased band width on all of the frequencies. This led to radios that had better

radio frequency rejection qualities, tighter frequency controls and, as a technological addition, more functionality. *To truly appreciate the capabilities of the modern-day radio you need to understand how the radio actually works.* A basic knowledge of the radio system will assist you in analyzing problems as well as allowing you to extract all the functionality the radio system offers.

## COMPONENTS OF A RADIO SYSTEM

A modern airplane radio system consists of a transmitter, receiver, on-board battery, on-off switch, and servos. The transmitter generates the servo control pulses, places them into a format suitable for transmission, and modulates them onto a radio signal. The receiver selects your transmitted signal, extracts the servo control pulses from the radio frequency, and sends them out to the individual servo. The servos receive their specific control pulse and convert the signal to a mechanical movement that allows you to control the airplane.

## HOW THE RADIO FUNCTIONS

A radio system is normally defined by the number of channels or available functions it possesses, and the method of encoding or modulation it uses. For example, there are 4-channel AM radios, 10-channel PCM radios, 7-channel FM radios, and a myriad of other combinations.

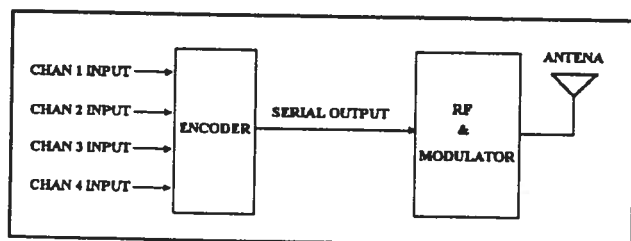


Figure 1

Referring to the figure, let's overview these areas:

**Channels:** Each channel in the radio carries one control pulse, which is destined for a servo in the aircraft. Each servo in the aircraft normally performs one function. A 4-channel system is capable of driving four servos, so a 7-channel radio would be capable of driving seven servos, etc. Most modern-day transmitters have two sticks, and a few switches. The sticks each require one channel per axis (left/right and up/down) and control the throttle, rudder, elevator and ailerons (four channels). The switches are divided into two types, those which modify the operation of another stick or switch, such as dual rate or mixing, and those which control specific aircraft functions, such as retracts or flaps. Switches which control functions require a channel and generate a servo control pulse, which is sent to the receiver. Switches which modify other functions do not require a channel, since their output is used within the transmitter to modify or limit other functions. Generally, the sticks are the proportional controls and the switches are "on/off" functions.

**Encoding/decoding:** The control pulses generated by the various sticks and switches on the transmitter cannot be directly applied to the radio signal sent between the transmitter and receiver. Therefore, the control signals are encoded into an acceptable format. Modern radio systems use either Pulse Positional Modulation (PPM), or Pulse Code Modulation (PCM) system. The technical difference between the two will be discussed later.

**Modulation:** Since the encoded control pulses cannot be directly sent from the transmitter to the receiver, they are modulated onto a carrier frequency. The carrier frequency is the frequency your transmitter operates on, such as channel 34, channel 48, etc. Two methods of modulation are used, AM or FM. AM is amplitude modulation where the amplitude (or strength) of the carrier frequency is altered to represent the data being carried. FM is frequency modulation

where the frequency of the carrier is altered to represent the data being carried.

One thing to remember; no matter what type of encoding (PPM or PCM), or what type of modulation (AM or FM), no two radios on the same carrier frequency (channel) may be operated together.

Before we begin to describe how a radio actually works, it is important to define some basic elements and terms to improve/increase your understanding. A basic element of the radio system that must be understood is the "servo pulse." Everything in the radio system functions around these pulses. Each channel of the radio generates a pulse with a width, which is varied between 1.0 and 2.0 milliseconds (ms). The width of the pulse is what determines the position of the servo arm. One pulse for each channel, with their varying pulse widths, are grouped into a string of pulses called a "frame." The transmitter generates and sends approximately 20 to 50 frames per second.

## THE TRANSMITTER

The purpose of the transmitter is to generate and transmit the servo pulses. At the transmitter we have sticks and switches whose sole purpose is to control the "width" of a pulse sent, ultimately, to your servo.

As an example, we will review the operation of a basic Pulse Positional Modulated (PPM) 4-channel radio, the simplest of the radio systems. Referring to Figure 2:

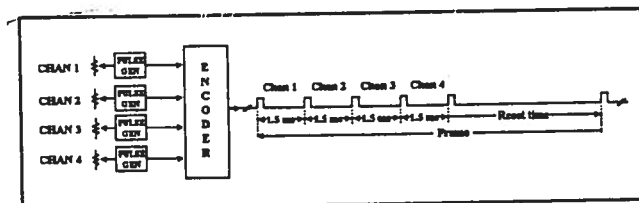


Figure 2

we see that the two transmitter sticks each control two channels. For now we will call these

Channels 1 through 4. Each axis, or channel, of the control stick is connected to a potentiometer, or "pot" for short. The pot controls the pulse width of a pulse generator. As stated previously, the pulse width varies from 1.0 ms to 2.0 ms with 1.5 ms being the pulse width when the stick is in its centered position. With both sticks centered, all four channels are each generating a 1.5 ms. wide pulse. All four pulses can not be sent at the same time. Therefore the pulses must be "encoded" into a format suitable for transmission and ultimately decoded by the receiver. To accomplish this, the pulses are placed in a specific sequence resulting in a string of pulses. The actual pulses sent is a serial string of markers defining the start and end of each pulse.

When both sticks are centered, the serial string would begin with a "start pulse" which would define the start of the Channel 1 pulse. Then, 1.5 ms later, a pulse defining the end of the channel 1 pulse and the start of the channel 2 pulse is sent. This would be followed after 1.5 ms by the end of the Channel 2 pulse and the start of the Channel 3 pulse. This would be followed after 1.5 ms, by the end of the Channel 3 pulse and the start of the Channel 4 pulse. Finally, this would be followed 1.5 ms later by the end of the Channel 4 pulse. If you should have a radio with more than 4 channels, the serial pulse string would continue for as many channels as your radio has. After the last pulse there is a reset period, which is required by the decoder. Then the whole pulse sequence starts over again. *This overall sequence from the start pulse to the end of the reset period constitutes a "frame."*

A closer look at the stick-controlled pulse generators will reveal that in order to achieve the serial encoding, they would not all start at the same time. The first channel pulse generator is triggered by the start marker of the frame. The second channel pulse is triggered by the end of the first pulse, the third channel pulse is

triggered by the end of the second pulse, and so on through all the channels.

Referring to Figure 3

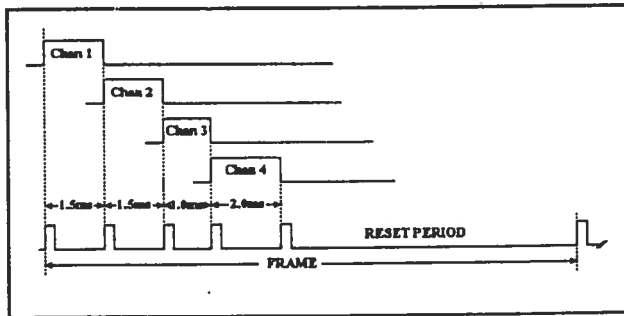


Figure 3

we see the graphic result of this sequential triggering. The pulse widths in this diagram vary. NOTE: Channel 1 pot is centered, Channel 2 pot is also centered, the Channel 3 pot is at the minimum and the Channel 4 pot is at the maximum.

The frame of pulses created above must be modulated onto a specific frequency that can be sent through the air to the receiver. This is accomplished by the radio frequency module. Although the generation and encoding of the pulses is specific to our equipment, the modulation and transmission of the signal uses standard radio transmission methodology. For this reason we will not cover the specifics of modulation and RF transmission.

## THE RECEIVER

The receiver captures the radio frequency signal sent by the transmitter, recovers (demodulates) the serial pulse string, and decodes the pulse string back into the pulse that is used to control the servos' movement. Refer to Figure 4

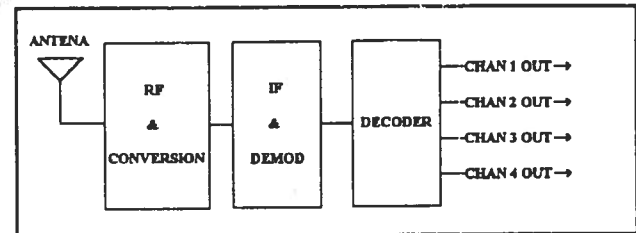


Figure 4

for an overview of the circuitry. As with the transmitter, only the receiver's decoding is specific to our equipment. The receiver's "front end" RF and conversion circuits, as well as the IF and demodulation circuits, utilize standard radio methodology. For that reason we will only address the decoding process.

Remember, the output signal generated by the transmitter is a frame and the frame is composed of a series of marker pulses associated with each channel of the system. Therefore, the receiver must receive the frame and then break it down into the individual signals or pulses associated with each channel. It must do this without becoming confused as to what signal goes to each channel. Imagine if the poor receiver became confused and sent the retract landing gear signal to the elevator servo! I think you would see some very tight loops! Anyway, how does the receiver break the frame down and distribute the signal to the appropriate signal? It is done with a decoder. The purpose of the decoder is to reverse the operation of the encoder. Its goal is to take the incoming string of pulses, return them to their original pulse width, and send them to the proper servo.

To understand the basics of this operation refer to the block diagram of a decoder. For all you circuit and electronic nuts, we know it is not technically correct, but bear with us for now. First, let's define each element of the diagram.

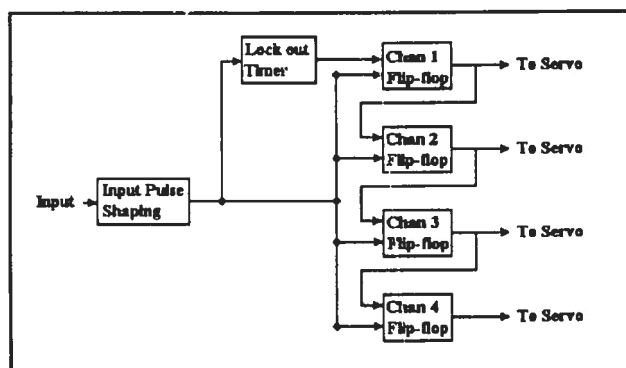


Figure 5

Input Pulse Shaping. This block represents circuitry which would clean up the input pulses from the receiver's demodulator.

Lockout Timer. This device's output is normally on and is turned off with each incoming pulse. It will time out and return to its "on" state when an input pulse has not been received for a predefined period of time.

Chan "X" Flip Flop. This device will turn "on" and "off" with each input pulse based on the status of the previous block. If the previous block is "on" it will turn "on." If the previous block is "off" it will turn "off" or stay "off" if it is not "on". Its output is positive when turned on.

With the decoder in the static position, it is ready to begin decoding the input signal. The static state for the decoder is for the lock out timer to be "on" and each flip-flop to be "off." We will again assume that both sticks are centered and the spacing between pulses is 1.5 ms.

When the receiver receives the start pulse, it will only turn on the "Chan 1 Flip-Flop." The "Chan 1 Flip-Flop" is conditioned to turn "on" because the lock out timer is "on." Channel 2 through 4 will not turn "on" because none of the previous channels are "on." Also, the Channel 1 pulse will turn the Lockout Timer off. 1.5 ms later the receiver receives the second pulse. This is the pulse which defines the end of Channel 1 and the start of Channel 2. Since the Lock-Out Timer

is now off, the only Chan Flip-Flop conditioned to turn "on" is Chan 2 Flip-Flop. Also, since the Chan 1 Flip-Flop is "on" and the Lockout Timer is "off," the Chan 1 Flip-Flop will be turned "off." The Lockout Timer will be reset again with this pulse, even though it has not turned back "on." The decoder has now sent a 1.5 ms pulse to Channel 1 and has just turned "on" the Chan 2 Flip-Flop. 1.5 ms later we will receive the third pulse. This is the pulse defining the end of the Channel 2 pulse and the beginning of Channel 3. Since the Lockout Timer is still off, the only Chan Flip-Flop conditioned to turn "on" is the Chan 3 Flip-Flop. Also, since the Channel 2 Flip-Flop is "on" and the Chan 1 Flip-Flop is "off," the Chan 2 Flip-Flop will be turned "off." The Lockout Timer will be reset again. The receiver has now sent a 1.5 ms pulse to channel 2 and has just turned "on" the Chan 3 Flip-Flop. This sequence will repeat itself through all 4 channels. This flip-flop circuitry is analogous to sorting mail. You're given a stack of mail and asked to place it in each of the mail boxes. This is essentially what the decoder circuitry in the receiver does.

After the receiver has processed all the channel pulses, there is a long enough reset period for the Lockout Timer to return to its original "on" position. This must occur before the next frame of pulses is received. This period would be longer than the maximum time between pulses, longer than 2.0 ms, yet short enough to ensure that it was reset before the next frame of pulses was received. A typical period of time would be 5-6 ms, which would allow the loss of a single pulse without the unit resetting. When the Lockout timer resets, it resets any Chan Flip-Flop that was left in the "on" position. This ensures that if we'd lost a pulse in the transmission, a Chan Flip-Flop would not be left "on." This also ensures that we will "sync" the receiver to the transmitter within one frame after turning "on" the equipment. Now the various channel signal pulses have been sorted by the decoder, and each pulse has been sent to its respective servo.

## PCM VERSUS PPM ENCODING

In the PPM encoding we see that marker bits, which are spaced the width of the servo pulse, are what is modulated onto the radio frequency. This means that the pulse sent by the RF module is of a time duration only. For example, if the signal generated by the elevator stick in the transmitter is 1.7 ms long, then the PPM marker pulses will be 1.7 ms apart. The receiver then receives this 1.7 ms-spaced signal, processes it, and sends it to the servos. This encoding scheme is simple and effective, and has become the accepted method for RC for the last 20 or so years. It has one serious drawback, however. If for any reason interference alters the pulse train in any way, the receiver's decoder will become confused, and the servos would be sent incorrect position data. This would produce erratic, random operation, commonly known as "glitching."

With the advances in microelectronics, it has become possible to design a cost-effective PCM system. In a PCM system, a microprocessor (computer) replaces the encoder found in the transmitter of a basic PPM system. In the PCM system, control stick positions do not control pulse generators but are inputs into A/D (analog to digital) converters, which convert their position into binary numbers. The microprocessor then assembles all the numbers from all the channels into a data string, calculates a checksum, and outputs a data frame to the RF module for transmission to the receiver.

Aside from sending a digital representation of the pulse width, the main difference between the PPM and PCM radios is the addition of the checksum. The checksum is nothing more than a "total" count of the binary codes generated for each channel within a specific frame. The receiver also has a checksum counter, and as the frame is received, the receiver's checksum counter "totals" the binary codes. Once a frame has been received, the receiver's checksum is compared with the checksum sent by the

transmitter. If the two totals are equal, the receiver passes the processed channel data onto the relevant servo. If the two totals from the checksum counters are different, the receiver discards that frame of data and the servos hold their current position.

This means that the Receiver now has a means to distinguish good data frames from garbage frames, i.e., frames that have interference-caused glitches in them. The receiver will then reject bad frames, and maintain the servos at the last known good position. This is known as "Hold." Some PCM radios have an added feature, called "Failsafe." If the Receiver has not received at least one good frame in more than one second (this delay is programmable in some radios), it will command the servos to a preset "failsafe" position (usually closed throttle, gentle turn, etc.). As soon as the receiver receives a good frame, it will come out of hold or failsafe, and send that position data to the servos.

This is why an airplane with a PCM radio will not exhibit the "jitters" like a PPM radio when an unwanted signal is introduced into the system.

Early PCM systems divided the servos' rotation into 255 discrete positions. This meant that the arc of the servo throw was divided into 255 steps and the servo pulse width generated by the decoder was based on the binary number 001 through 255. A binary 001 would represent maximum throw in one direction with a binary 255 representing maximum throw in the opposite direction. A binary 128 would represent centered. The binary 000 is not used in servo positioning.

Modeling demands soon forced manufacturers to provide the more precise 511 step system, and finally the "stepless" 1023 system. These higher-resolution systems required the transmitting of more data from the transmitter to the receiver. However, the rate of data transmission remained constant; therefore, this reduced the number of updates per second that

the servo received. This meant the servo response was perceptibly slower for a PCM radio than a PPM radio.

A typical PCM radio sends about 20 frames per second versus the 50 frames per second sent by a PPM system. This is due to the amount of information that must be compiled and processed by introducing computer circuitry into the radio. The computer utilizes the binary system for compilations. This is convenient because a bit, or binary position, is filled with either a "1" or "0." This allows the computer circuitry to either be switched on or off depending on whether it receives a "1" or "0" bit of information. Each binary position is considered a bit and is a multiple of two from the previous position. Base 10 system numbers that we work with can be converted to base 2 or binary system. However, a binary number takes more positions to represent a base 10 number. The base 10 number "16" is represented by the binary number "00001" in the binary system. This number takes 5 bits of information to represent. Base 10 number "32" is "000001" in binary and takes 6 bits. Base 10 "512" is "000000001" in binary and takes 9 bits. This binary code allows the radio computer to send the many discrete servo positions required from modelers. To achieve 255 steps, a binary number consisting of 8 data bits per channel must be sent. For a 10 channel system this would be a total of 80 data bits per frame (10 channels x 8 bits per channel equals 80 bits of information). A 511 step system would require transmitting a binary number consisting of 9 bits per channel for a total of 90 bits per frame. A 1023 system would require a binary number consisting of 10 bits per channel for a total of 100 per frame. Adding the sync and checksum data extended each of these an additional 16 to 20 bits. All this information transmission takes time and therefore fewer frames per second are compiled.

The demanding modeler wanted high update speed (frames per second) so PCM servo movement would keep up with PPM servo

movement. However, the RF channel bandwidth (FCC 1991 requirements) limits the number of bits per second that can be transmitted.

Therefore, radio designers came up with clever schemes to allow the use of high resolution (9-bit and 10-bit) with limited bandwidth.

Many current PCM designs inter-weave absolute position and "delta," or position change data, in each alternate frame. The delta data is only 6-bit data and tells the Receiver the difference between the current position of the servo and its position given in the previous frame. In this way you save about 20% of your RF bandwidth, which allows 10-bit with delta to operate as fast as an 8-bit without delta.

Although the PCM method of operation will eliminate "jerking" caused by interference, it should be noted that PPM and PCM encoding/decoding has nothing to do with the capability of the receiver to reject unwanted signals.

The PCM concept of encoding/decoding was originally developed in the pre-1991 era to address the interference problem of those days. With the new narrow band, dual conversion receivers used today, PPM receivers may work as reliably as PCM receivers in many areas. If you're flying in an area where interference is not being experienced by the PPM radios, then moving to a PCM unit will offer no advantage. In today's narrow band environment, FM and dual conversion usually reduces the receiver's susceptibility to interference over AM or single conversion, with dual conversion being the most influential factor.

The term "PCM" and "Computer Radio" are not analogous. Although all PCM radios are computer radios, not all "computer radios" are PCM. Today's computer radios are available in both PPM and PCM versions. The "computer radio" is probably the most significant advance of the last decade. In the computer radio, the transmitter's encoder has been replaced with a microprocessor. Once this was done, the

capability to control the servo pulse became unlimited. Today's computer radios not only allow full control over the throw, rate, linearity, and reversing of the servos' operation, but also provide many additional mixing features while allowing you to set up and store these configuration for multiple aircraft.

If cost is a major influence in the purchase of your radio, then today's FM, dual conversion, PPM radio, in either a 4 or 6 channel configuration is an excellent buy. If you can afford the additional cost to step up to a computer PPM radio, we would highly recommend it. Finally, if minor interference is a problem in your area, then the PCM option would be desirable.

When purchasing a PCM system, the higher resolution means more precise control of the airplane. However, we personally believe that the novice, sportsman, advanced and master flyer probably would not notice the difference between the 512 and 1024 bit processors. We have been told that world-class flyers do notice a difference between the 512 and 1024 processors. *But don't let your ego get in the way of your pocketbook.* If you're having a problem making a loop round, or the symmetry of your maneuvers is not correct, the faster processor won't help you.

*Regardless, before you buy any unit, always check with individuals in the areas where you plan to fly to determine if there are channels which are susceptible to interference.*

## THE SERVO

Servos are electro-mechanical devices. They receive an electrical signal and output a mechanical movement. Each servo is controlled by one channel of the radio system (we will not confuse the issue with mixing channels at this point).

Regardless of whether the system is AM or FM, using either PPM or PCM, the pulse from the receiver to the servo uses the same basic concept. The width of the pulse controls the output arm's rotational position. Although some of the early radios used different pulse widths, all current radios, to our knowledge, use a standard width. This standard pulse width varies from 1.0 ms to 2.0 ms with 1.5 ms being the center.

Internally within a servo there is a pulse generator, comparator, pulse stretcher, motor driver and servo motor. Referring to Figure 6:

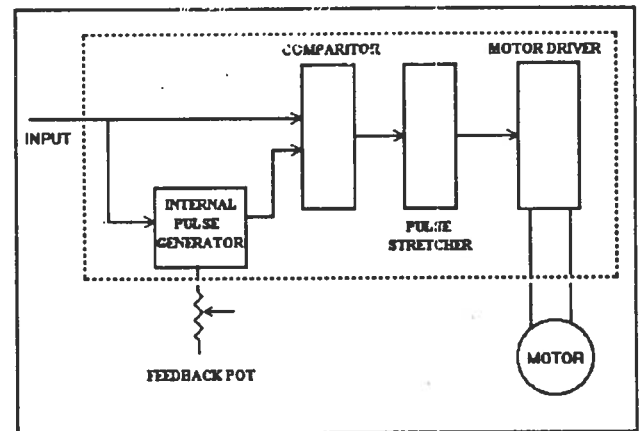


Figure 6

we see a block diagram of these components. These components work in harmony to transform the input electrical pulse into mechanical movement. As the signal from the receiver enters the servo circuitry it trips the servo's own pulse generator, which varies its pulse width based on the output arm's position. The output arm moves a variable resistor or potentiometer (called a 'pot' for short). This varies the internal pulse generators pulse width from 1.0 to 2.0 ms, with the pulse being 1.5 ms when the arm is in the center (just like the transmitter stick).

The pulse generator within the servo only generates a pulse when an incoming pulse is received from the receiver. The receiver pulse

"triggers" the servo's pulse generator. What we now have in the servo are two pulses, the pulse from the receiver and the servo's internally generated pulse. Both pulses start at the same time, but, depending upon the position of the transmitter stick, versus the position of the servo arm, they may not end at the same time. At this point both signals are inputted into another circuit in the servo called the "pulse width comparator." This circuit compares the input signal from the transmitter to the internally generated signal. If the signals are equal the "pulse width comparator" sends no signal to the next circuit. If the signals are not equal the "pulse width comparator" sends a signal based upon whether the input pulse was longer or shorter than the internal pulse. It does not matter how much longer or shorter the incoming pulse is than the internally generated pulse.

The output of the "pulse width comparator" feeds a "pulse stretcher," which in turn feeds the "motor driver circuitry." The function of this pulse stretcher is to "stretch" the small differential pulse generated by the pulse width comparator long enough for the next pulse to arrive. This eliminates the servo motor being pulsed 50 times a second.

The motor driver circuit determines the polarity of the power applied to the servo motor. Depending upon the signal it receives from the pulse comparator, it will run the motor clockwise, or counter-clockwise.

The servo motor is a DC, or direct current motor. If we connect a power source to its terminals it will turn in one direction. If we reverse the polarity of the power connections it will run in the opposite direction.

Let us observe the servo operation when both the transmitter stick is centered, and the servo arm is centered. Under this condition the incoming pulse would trigger the servo pulse. Both pulses would start at the same time and end together 1.5 ms later; when this occurs, the servo does nothing. Now move the transmitter

stick in one direction. As stated before we now alter the width of the pulse to the servo. For this example we will say that the pulse became wider. As before, the input pulse triggers the servo's internal pulse generator and the two pulses start together. However, this time the input pulse is longer than the servo's internally generated pulse and they do not end together. These two pulses are introduced into the pulse width comparator. The pulse width comparator then generates an output to the motor driver circuits, signifying that the incoming pulse is longer. We will assume that when the input pulse is longer than the internal pulse, the servo motor will rotate clockwise. As the output arm of the servo rotates, the feedback pot rotates as well. The feedback pot adjusts the width of the next pulse generated by the internal pulse generator.

With the next frame comes a new servo pulse which triggers the internal pulse generator again. This new set of pulses is then sent to the pulse width comparator which again compares the signals. If the signals are still not equal, the pulse width comparator sends a signal to the servo driver circuit to rotate the servo motor farther in the clockwise direction. The servo motor then rotates the feedback pot controlling the internal pulse width generator. The next frame's servo pulse starts the sequence all over again and when the signals are equal, the pulse width comparator stops sending signals to the servo driver circuit to drive the motor. If we move the stick of the transmitter a little more the whole cycle of sending and comparing starts over until the pulse widths match.

If we were to return the stick to neutral, the input pulse would be shortened, the pulse comparator would detect this shorter input pulse and signal the motor driver to run the motor counterclockwise until the pulses matched.

Because the servo only moves when it receives an input pulse which does not match its internal generated pulse, our servos are defined as "error correcting" and not "self centering." In

other words, if we were to lose the signal to the servo, it would remain wherever it was last positioned.

In order for our servos to faithfully track the transmitter stick position, the radio system must provide the servo with many pulses per second. The servo then compares and adjusts its position based upon these pulses. The number of frames generated, received and processed is approximately 20 per second for a PCM and up to 50 per second for a PPM system. To us, that's *fast!* However, in the computer industry, it's relatively slow.

## BATTERY MAINTENANCE

Radio and battery maintenance is important for the longevity of your airplane. Today's radios require very little maintenance. If you don't abuse your radio by crashing or not protecting the equipment, the system will virtually take care of itself. However, batteries, the driving force behind the radio system, are another issue. It's important for you to be attentive to your batteries' condition.

With the exception of some "economy" radios which use alkaline batteries, all of today's modern radios use rechargeable nickel-cadmium (NiCd) batteries. A single NiCd cell, regardless of its size, will only produce 1.25 volts. Since most receivers require 4.8 volts and most transmitters require 9.6 volts to operate, a battery pack must be used. The battery packs used for the receivers in our aircraft are manufactured by connecting four individual cells in a "series" configuration. This means that the positive end of one battery is connected to the negative end of the next battery, similar to a string of sausages. This is in contrast to a "parallel" configuration where all the positive ends of the batteries are connected together and all the negative ends are connected together. The difference between the parallel and series configurations is the amount of voltage and current capacity that can be

attained. Series battery packs develop the combined voltage total of the individual cells while providing the current capacity of a single cell. The parallel cell battery pack configuration develops the voltage of a single cell of the pack, but the combined current capacity of total cells of the battery pack. Four 500 milliamp (or ma) NiCds connected in series will produce a 4.8 volt pack ( $1.2 \text{ volts} \times 4 \text{ cells} = 4.8 \text{ volts}$ ) with a current capacity of 500 ma. Four 500 ma NiCds connected in parallel will produce a 1.25 volt pack with a current capacity of two amps ( $500\text{ma} \times 4 = 2000 \text{ ma}$  or two amps). To obtain the 9.6 volts required for our transmitters, radio manufacturers use a pack of eight series-connected cells.

There is a drawback to the series configuration that must be understood. Because all the series battery cells are connected together like a chain, they also perform like a chain. The chain is only as strong as its weakest link. Consequently, the battery pack in the radio system is the same: It is only as reliable as the inferior cell in the pack. Therefore, if one of the four cells of the pack fails, in a shorted (closed) position, the voltage of the battery pack will drop accordingly. A shorted failure means that the battery creates a direct short and the cell adds no voltage to the battery pack, only allowing the current to flow through it. An open cell failure means the cell will not allow the current to flow through the battery pack. If a single closed cell failure condition occurs you will probably be able to save your airplane, because most receivers will operate on the remaining 3.6 volts, although the servos will be sluggish. However, if a cell fails in the open condition, no current flows and all electronic functions cease immediately. *Good news: most cell failures are of the shorted or closed type. Open failures are normally in the wiring or switch.*

Improperly charging your batteries is probably the main cause of early failure. A NiCd battery should *never* be overcharged. Internal heat is generated within the battery during

overcharging, which causes free oxygen, which attacks the separator material, causing it to decompose and eventually lead to an internal short.

Most radio systems come with a charger which is designed to recharge your batteries from a completely discharged status, in about 16 hours. This charger will normally not damage a cell if left on accidentally, but even so, it should not be left on the batteries for over 24 hours. Since we seldom fly until our batteries are dead, they seldom need the full 16 hour charge. *Feel your batteries during the recharging; if they're getting warm, you're overcharging them and should adjust your charging period accordingly.* If you're charging with an after market "quick charger" the potential of damaging the pack is quite high.

It is of utmost importance to check the battery pack of both the transmitter and receiver frequently. If either battery pack should fail ... it's back to the building table for a new airplane. To evaluate the condition of a battery pack, you have to monitor its remaining capacity. When flying, we expect to get about six flights from our radio system. After six flights the batteries are generally close to the critical level. If they wear down too far the radio fails, which generally means the end of the airplane. *Monitor your batteries by checking them before each flight.* Do this with a meter that puts a load on your batteries. If you use a meter that does not put a load on the pack, the reading will probably be erroneous, because rechargeable batteries will do what's known as "skin": the voltage will rebound back up after it has been unloaded. The meter will read this erroneous skinned voltage if it doesn't place an electrical load on the battery. Therefore, always use a meter that applies a load to your battery packs to attain the actual available voltage. Although constantly metering your battery pack between flights is a very good way of monitoring its condition, the only way to determine the status is to perform a "cycle". NiCd batteries do not have a linear discharge curve.

In a linear discharge curve when the battery was half discharged it would read half voltage. What happens in our NiCd packs is that the voltage drops quickly to a plateau, about 4.8 volts. The pack slowly loses voltage on this plateau as time ticks on until the voltage level reaches a certain point, about 4.5 volts. Then the voltage decreases rapidly below the requirements of the radio system. When this happens the radio no longer functions. Down comes da plen! Funny, when something goes wrong with the plane, it never just stays in the air until you can correct it. This break point or "knee" on the discharge curve happens quickly. Therefore, it's very difficult to monitor the battery capacity down to the last flight with a meter. However, there is slightly more scientific way of knowing the condition of the pack than just trusting to fate. This is through the use of a battery cycler.

A battery cycler discharges the battery pack much the same way as flying the airplane does. The cycler places a prescribed load on the battery pack and times how long it takes for the pack to discharge to a certain point. The advantage of the cycler is that the batteries can be discharged to the critical point on the ground without fear of losing an airplane. This allows you to determine the initial capacity of the battery pack, and, over time, see if it's deteriorating. Discharging rechargeable batteries, whether in the act of flying, or closely monitored cycling, is good. It's bad if the batteries discharge faster and cease functioning sooner than you anticipate.

Different battery cyclers apply different loads on the battery. The load divided by time results in the "rate of discharge." With different battery cyclers on the same battery pack, the duration of discharge will vary. However, it's not necessary to know the rate of discharge, but only the actual discharge duration of the battery pack. Therefore, if you cycle your batteries, always use the same battery cycler and just track the duration of discharge.

Now that you know how batteries are configured and how to cycle them, the next question is "when."

A new battery pack should be cycled three times prior to using. The times for each cycle should be recorded and compared. Normally a new pack will increase its time with each charge. If the times are within a few minutes of each other, go ahead and install the pack in your airplane. If the times drop off and there is a spread of 10% or more, then do not use the battery.

Once in the airplane, cycle the batteries about once a month. Do not do it each time you fly. This stresses the cells unnecessarily and will decrease the life of the battery pack. Monitor the times and compare them to the original values. When the time drops below 10% of the original duration, watch the battery pack closely.

In addition to determining the condition of a battery pack, the cycler is the only accurate way you can determine the amount of flying time you had left after leaving the field. As soon as you get home, place your battery pack on the cycler and discharge it first, without first charging it. The discharger will read the amount of time left in your pack. Let us assume that you flew four flights and the pack discharged in 50 minutes. Compare this duration with the original duration of the pack and you can determine the capacity you had left. For instance, if the capacity of a fully charged pack was 100 minutes and you had 50 minutes left after flying, then you had used 50% of the pack's capacity. In the above situation, you could have probably safely flown six or seven flights on that pack. You could not have flown eight because the pack would have gone dead just as your wheels touched the ground. That's cutting it too close.

*Cycling a battery pack also helps eliminate a condition called "memory." Memory, in a battery pack, occurs when a battery pack is repetitively recharged without fully discharging it. This happens when you constantly fly only two or*

three flights, and then go home and recharge the battery pack. A "short cycle memory" will set in, and get you the day you try to fly any extra flights. The battery won't be able to provide its maximum discharge current and you'll run out of battery sooner than you think.

To alleviate this problem, use the battery cycler. The battery cycler discharges the battery pack fully and then recharges it or sounds an alarm that lets you know to stop discharging and recharge the battery pack. If you cycle your battery packs about once a month, memory will not be a problem.

Some radio system transmitters do not allow cycling. In these units the manufacturers have installed an electronic component called a diode. The diode allows current to flow in one direction only. If a diode is installed in your radio system's charging circuit, you can only charge the batteries. The diode prevents current from flowing out of the battery via the charge connector. Therefore, if you do have a system that prevents you from cycling your batteries, the only alternative is to remove the battery pack and attach it directly to the cycler or to watch the voltages of the transmitter very closely. Also, quit when you're ahead of the voltage game. In addition to cycling or monitoring the voltage of your batteries, it's wise to inspect them visually.

Inspect your battery packs frequently. Look for the white chalky stuff you see on old batteries. If this should appear, even in the smallest quantities, the battery pack is suspect and should be replaced. In addition, it's always a good idea to replace the battery packs on a routine basis.

Although NiCd batteries will not last forever, it's not uncommon for a pack to last five years. To be safe, you may want to consider replacing them every two or three years. This is cheap insurance. A set of battery packs costs less than \$75. If one of the cells in either pack should fail, it may cost you a whole lot more than \$75, not to mention the amount of time. It's just not worth it.

As a friend of ours says, "Don't fall in love with your batteries!"

## BATTERY AND RECEIVER INSTALLATION

After battery maintenance, properly padding the battery and receiver is very important. On 4-cycle airplanes, because of the vibration, the receiver should be wrapped with a minimum of 1/2" of good foam rubber. The rubber should be the closed cell variety sold by Sig or other reputable manufacturers. The foam rubber cushions the fragile crystal. The crystal in your receiver is similar to the element in a light bulb. It does not take much to break it and with the vibration present in airplanes, the crystal needs all the help it can get.

ABOVE ALL, DO NOT GLUE THE RECEIVER DIRECTLY TO THE FUSELAGE OR FASTEN THE RECEIVER IN THE AIRPLANE DIRECTLY WITH VELCRO WITHOUT FIRST SURROUNDING IT WITH FOAM RUBBER.

If you mount the receiver directly into the airplane you're flirting with disaster. We always recommend cutting back on all the material you can in order to lighten the airplane, but eliminating foam from the receiver is *not* part of the weight-saving program. In addition, we wrap the foam-covered receiver with a plastic bag. This keeps oil and dirt away from it, which might sound crazy, but take it from us, a ruptured fuel line in a pressurized fuel system can make a real mess of the radio compartment! It has happened to us and we pass along the knowledge in hope that if it happens to you, your receiver will be enveloped in a plastic bag.

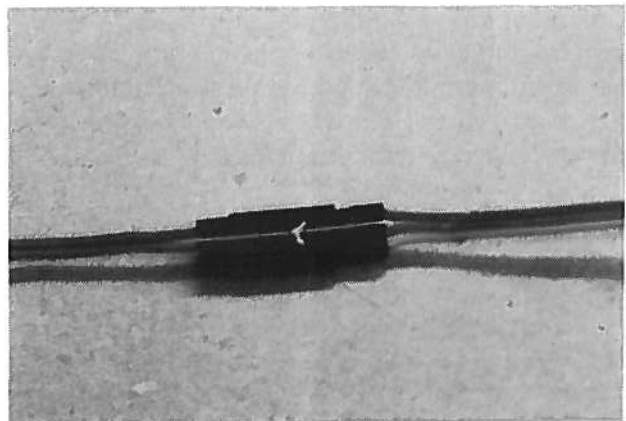
*Other than battery care, receiver foam, a plastic bag, and keeping oil and dirt away from the servos, there is very little maintenance for the radio system.* If you have a problem with your radio, send it to a reputable repair shop. This also includes checking over the radio in the event of an unplanned landing (we hate to use the word "crash"). If you have a mishap and

have to send the radio in for a check-up, or if you have a new radio, do *not* install it in your favorite, brand-spanking new, high-tech airplane: install all the checked or new radio gear in one of your old beater airplanes. This way if you lose your beater airplane, you're not out a lot of time and money. Do not believe that radio repairmen are infallible and your radio will be perfect. They are human and sometimes make mistakes.

*Always fly a checked or new radio a minimum of 15 flights before installing it in your prize airplane.* However, if you have any problem, pull the radio out of the airplane and send it back to the repairman. They prefer to fix radios that are in one piece as opposed to a bucket full of pieces, with a nasty letter from an owner.

## SECURING RADIO CONNECTIONS

Maintaining the integrity of standard plug-in radio connections has always been a concern of builders. Because they're friction connections without a positive latching system, they run the risk of disconnecting. Builders have used electrical tape, heat-shrink tubing and little plastic connectors to ensure the connections won't inadvertently disconnect. We ran across this simple back-up restraining system to ensure the connectors don't disconnect: Thread unwaxed dental floss or heavy carpet thread through each end of the connector, parallel to the wires; then tie off the ends and place a drop of CA on the knot. This restraint is neat, easy to lace through wing holes and extremely positive. Consider this back-up system the next time you install the radio in your airplane.



## Chapter 15 ADDITIONAL TOPICS

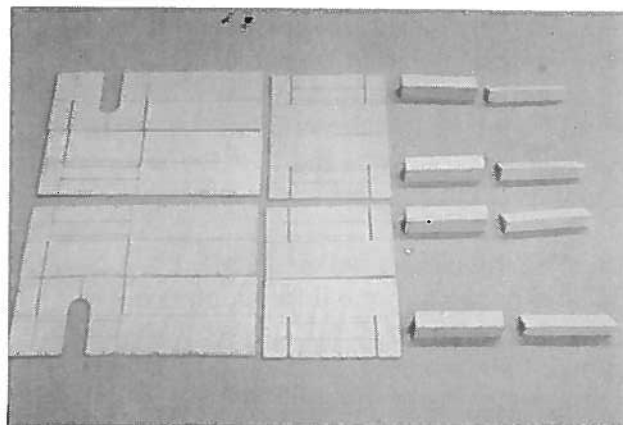
### LANDING GEAR SUPPORTS

A short time ago a small article on building a lightweight landing gear support appeared in the NSRCA *K-FACTOR*. There was a picture and a little verbiage. We looked at that for the longest time and then finally figured out what it was they were explaining. We took some time and built this lightweight landing gear support into one of our airplanes. We believe it is far superior, for a number of reasons, to the plywood plates included in most kits. Not only are they less than half the weight of the plywood plates but they are the same strength; we found this to be true because of the larger amount of gluing surface area and the way the forces from the landing gear are distributed into the wing. We now have more than 700 flights on a 120-size airplane and the supports are holding up without problem. These supports are like Timex watches: " ... takes a licking and keeps on ticking."

These supports are built out of 1/32" plywood. It's important that you use plywood and not a bass or spruce wood. The perpendicular grains of the layers of the plywood help with distributing the forces. How do we know this? The second time we built this support system we mistakenly used bass and thought there wouldn't be a difference. *Wrong!* After a few solid landings, we noticed that the sides of the box had sheared along the grain. We had to reinforce them with another piece of 1/32" plywood. Had we used plywood this would not have happened. We're flying the SL-1, 120-size airplane with this configuration and are not having any problems. If you're concerned, increase the plywood thickness to 1/16" and use the same configuration; this would allow enough of a safety factor to accomplish the task. At the end of this chapter we have included a sheet that shows the dimensions for Supra main landing gear incorporated into a SL-1 wing. Minor modifications are required to incorporate the

landing gear box into any wing with a plug-in wing configuration. We admit the first time you do this the instructions and pictures are a bit confusing. However, review the landing gear plan sheet and the instructions a few times and the concept should become much clearer.

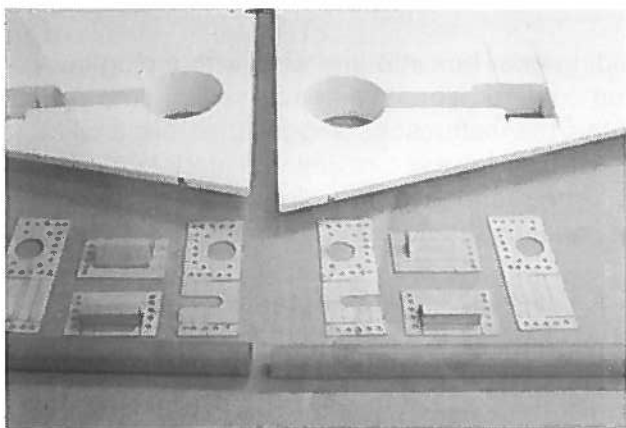
**15.1.** Our gear boxes perform two functions. They replace the false rib out at the tip of the phenolic tube and also support the landing gear. To size the supports, determine the landing gear system you're going to use. Then size the sides of the "box" around the landing gear base. The thickness of the wing determines the height of the box. We use the conventional Supra landing gear system and start with strips of 2"x12" plywood. Draw centerlines parallel to the 12" axis on the pieces. Divide the piece into four sides of the box. Cut out the pieces and drill lightning holes in each side. *Remember, you have to make a left and a right support.*



Gear Box Components Cut And Displayed

**15.2.** Cut the landing gear supports to length. Use 3/8"x1/2" square bass or spruce for these supports, backed by 3/8"x1/2" triangular balsa stock for just a little more "beef." The triangular stock distributes the forces more evenly around the box and into the wing. Without the triangular stock, you run the risk of concentrating the entire

landing force over too small an area and are inviting failure.

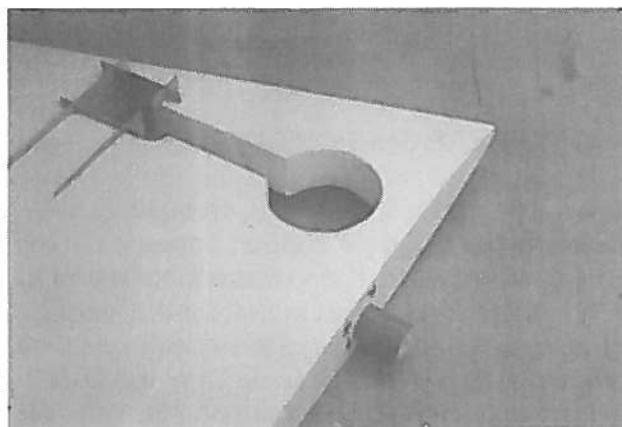


Components Arranged And Supports Glued In Place

**15.3.** Once the pieces are cut, slide them together for trial fitting.

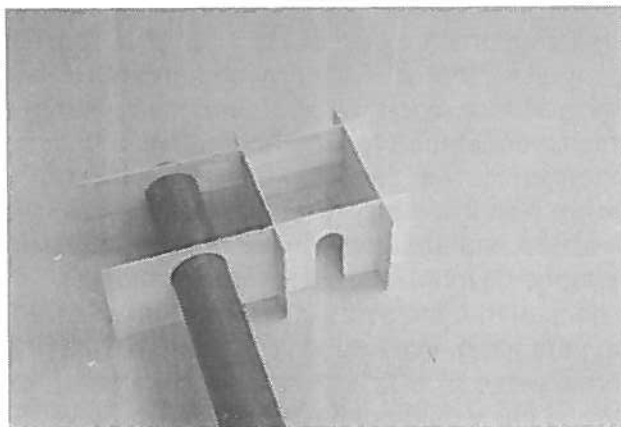
**15.4.** Lay the box over the wing core in the proper location and trace the pattern on the wing. We honeycomb our own wings and have incorporated the landing gear box into the honeycombing templates. If you don't have a honeycombing set-up, cut out the pattern traced on the wing with a sharp X-Acto knife. The flanges can be cut using a hacksaw blade worked from side to side as you cut the groove. Take your time because the fit in the wing core is important in the success to this support.

**15.5.** With the pieces assembled, but not glued, install the boxes into the appropriate wing panels. Center them in the wing section. Apply graphite, from a pencil, onto the end of the phenolic tube. Insert the tube into the wing panel until it comes in contact with the landing gear box side. Rotate the tube to form a circle where the phenolic tube will penetrate the side of the plywood side.



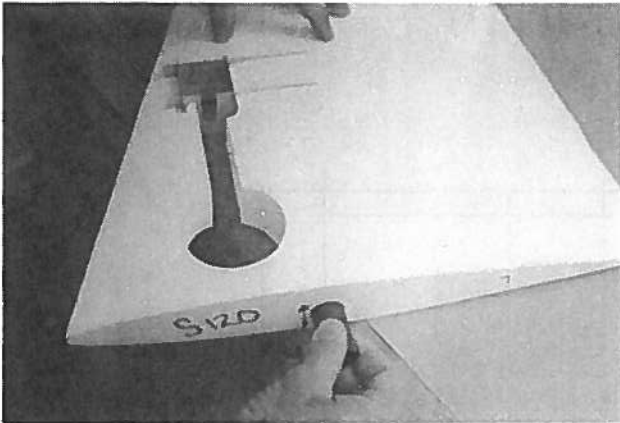
Phenolic Tube & Box In Wing Panel

**15.6.** Remove the tube and plywood box from the wing. Identify where the mark for the phenolic tube is on the side of the box and cut out the circle using a jig saw. Begin by cutting the hole smaller than the phenolic tube. Then, using sandpaper and a large diameter wood dowel or a piece of PVC tubing, enlarge the tube so the phenolic tube just slides into the hole without too much clearance. Repeat this process for the outboard side of the box.



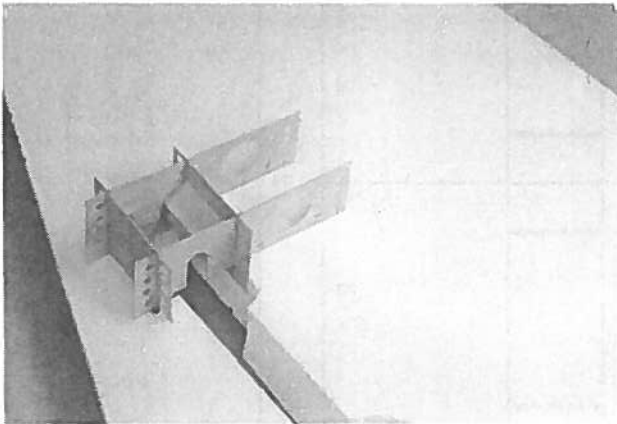
Landing Gear Box and Phenolic Tube Dry Assembled

**15.7.** Once the holes are cut into each side of the box, re-assemble the box, slide it into the wing panel and slide the phenolic tube into the wing panel and through the plywood box sides. Do this to ensure the assembly fits together correctly. Once satisfied that all the pieces fit together, remove the tube and plywood box from the wing.



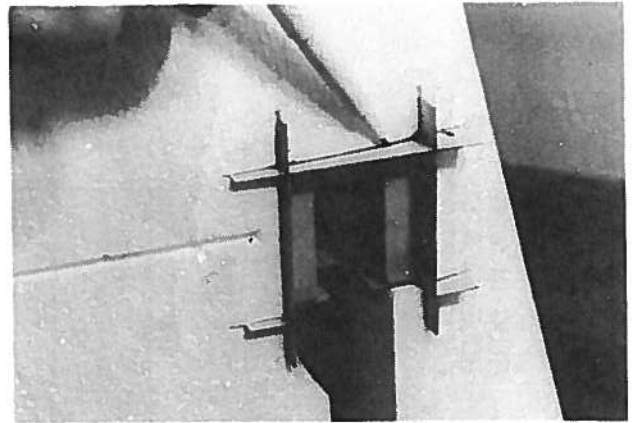
Box & Phenolic Tube Installed in Wing Panel Without Adhesive

**15.8.** Make sure that everything is square and begin gluing the assemblies together.



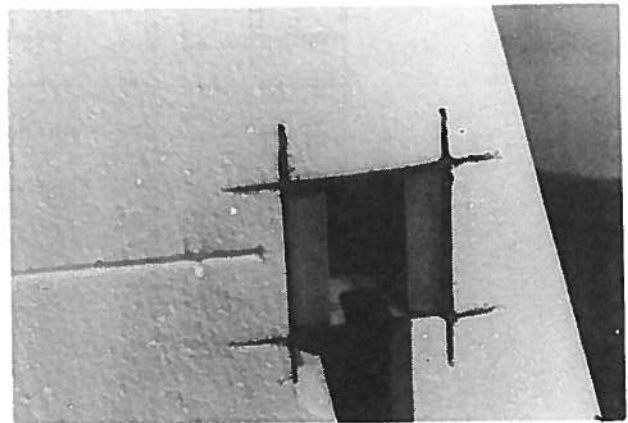
Boxes Assembled And Glued

**15.9.** When you can slide the support into the wing core, trace the outline of the core on the support sides. Remove the support from the wing core and remove the excess material, using a cutoff wheel on your Dremmel or your X-Acto knife. Slide the support into the wing core and check it for fit.



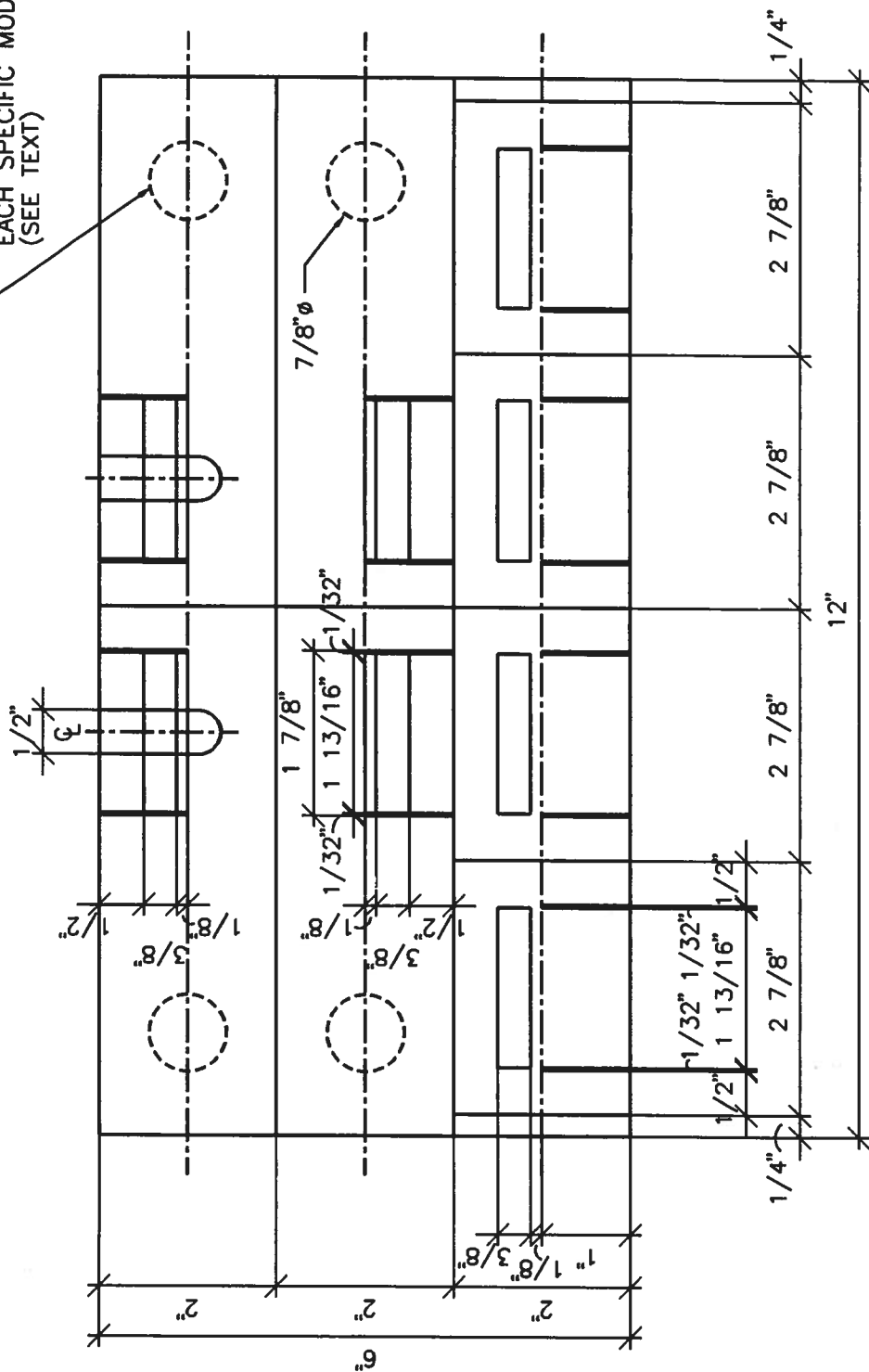
Outline Of The Core On The Gear Boxes

**15.10.** Sand the support if it is extending above or below the core. Slide the support out and apply epoxy to the core and the support sides that are in contact with the foam. Slide the support into the wing core and let it cure.



Landing Gear Box Installed In Foam Core

**15.11.** Voila! Your gear support is now complete.



# LANDING GEAR BOX DIAGRAM

## FUEL TANK SUPPORT

One of the chronic problems facing many builders is how to secure the fuel tank inside the airplane radio compartment, securely and lightly, and still maintain access. In the past, most people have taken the tank, wrapped it with foam rubber and jammed it in the nose of the airplane and then tried to forget about it. This procedure has three inherent problems:

First, all that foam rubber weighs something and when you're trying to cut as much weight from the airplane you don't need to add a wad of foam rubber as dead weight. One wrap of foam rubber around your 12- to 16-ounce tank weighs one ounce. You've worked very hard to eliminate weight from the sheeting only to add it back in foam rubber.

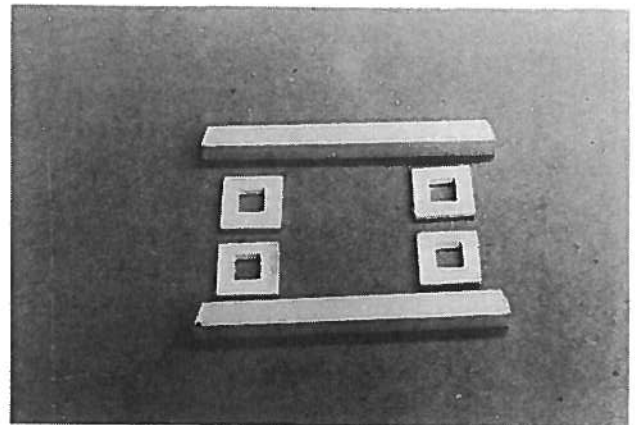
Second, your access is very limited with the tank in the nose of the airplane.

Third, a full fuel tank can weigh as much as a pound (16 ounces of fuel is approximately one pound). Imagine yourself taking off with a pound of fuel in the nose of your airplane. You do your procedure turn and start your trim pass, quickly trim your plane for straight and level flight, and all is well. Now you start into your sequence; the first few maneuvers are going well with the required straight and level lines connecting each maneuver. But then you notice that the nose of the airplane is rising between maneuvers and it appears your trim is off. You scramble for a click or two of down elevator and you're back to straight and level. This continues through your flight ... the nose slowly starts to rise as you continue your flight and you adjust with more clicks of down elevator. What's happening is that you *are* changing your trim by having your fuel tank in the front of the airplane and by burning the fuel out of the tank. As you eliminate fuel you eliminate weight. As you eliminate weight anywhere, except the plane's center of gravity, you change the trim characteristics of the airplane. Once you realize that having the tank

in the nose of the airplane is not the greatest location, where can you place it?

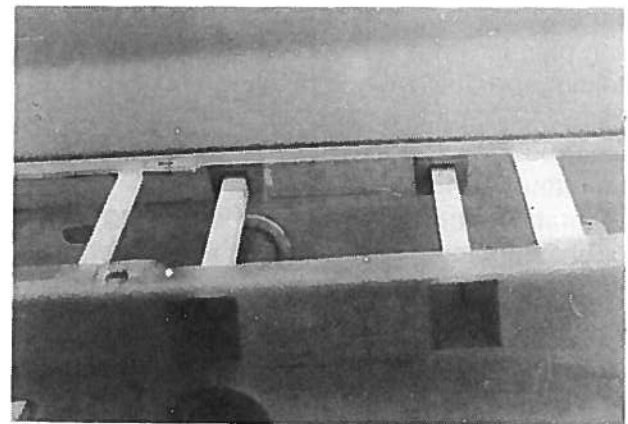
We wrestled with this problem for a long time. A friend finally showed us his tank support system. The following is how he solved the problem:

**15.12.** Cut two pieces of square 3/8" hardwood stock to the exact width of the inside of the fuselage. Then cut four squares of lightweight plywood approximately 3/4" square with a 3/8" square hole in the center. Glue the squares to the sides of the fuselage with either epoxy or CA in the locations desired. After the adhesive has cured or dried,



Support Components For Fuel Tank

spread the fuselage and insert the 3/8" square stock in the holes. This is the support for the tank bottom.



Fuel Tank Supports Installed In Fuselage

**15.13.** Screw four screws into the supports to fasten four pieces of Velcro™, which will anchor the tank. Don't forget, Velcro™ comes in hook and pile sections. Make sure you have a piece of "hook" and "pile" on each support or nothing will work.



Velcro Supports Installed To Retain Tank

If you need to remove the tank to access the radio equipment below the tank, separate the Velcro, spread the fuselage, remove the 3/8" stock, and in the amount of time it took you to read this sentence, you can open the radio compartment for easy access. This approach allows the tank to be located above the center of gravity, makes the radio compartment accessible, and is lightweight.

## RETAINING PLUG-IN WINGS

Recently, a few of our friends who have been flying plug-in wings have experienced problems retaining the anti-rotation pins in their proper position. Since this has not been an isolated case, and the potential exists for others to lose their planes by losing the engagement of the anti-rotation pins in the side of the fuselage, we thought we should disseminate the information and thoughts we have on the subject.

In years past, when the only wing configuration was the single or one-piece wing, the fastening system holding the wing to the fuselage was four wing bolts. If you happened to forget to put one in, or one broke, you had the advantage of

having three others in place to hold the wing on the fuselage. The system offered a high safety factor.

However, with the advent of plug-in wings, and the ability to slide on each wing panel, comes the problem of securing the wing panels in place. Securing the panels is done by using bolts, springs, rubber bands or a solid link. Bolts can be inserted at the end of the tube through the wing panel threaded into the aluminum tube, by using a fastening system inside the fuselage that joins the two wing halves with a solid piece of material, or a set of springs or rubber bands hooked over screw hooks that are fastened to each wing panel. Along with these speedy fastening systems comes the danger of having only one link joining the wing halves to the fuselage. If you lose the fastening system, the panel(s) pull away from the fuselage, disengage the anti-rotation pins and the next maneuver you perform is a uncontrollable snap roll to the ground.

Very rarely have we seen a back-up fastening system hold the panels to the fuselage if the primary system fails. *It only takes the loss of one of your favorite airplanes for you to realize that there needs to be some redundancy in the system.* After discussing this situation with other flyers, we came up with a back-up fastening system that works to hold the wing halves on if the primary fastening system fails.

All plug-in wing designs use the anti-rotation pin system. We make one anti-rotation pin on each wing panel longer so that it slides into the fuselage an additional 1/4". Then we just slide a washer over the anti-rotation pin and then drill a hole for a retainer clip. Install a retainer clip and you have a back-up fastening device for your plug-in wings.



Plug-In Wing Retaining Clip Detail

*It does take just a few seconds longer to insert the retainer pin. However, if your primary fastening system fails, a few seconds of prevention at the beginning of your flying session will prevent a hundred hours of building a replacement aircraft.*

## DEFLECTION GAUGE

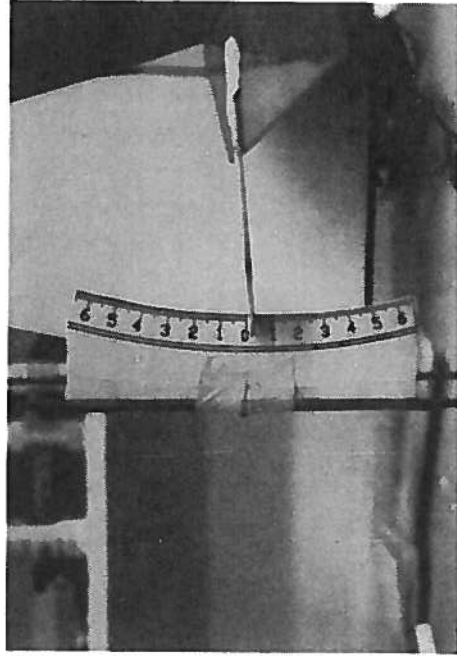
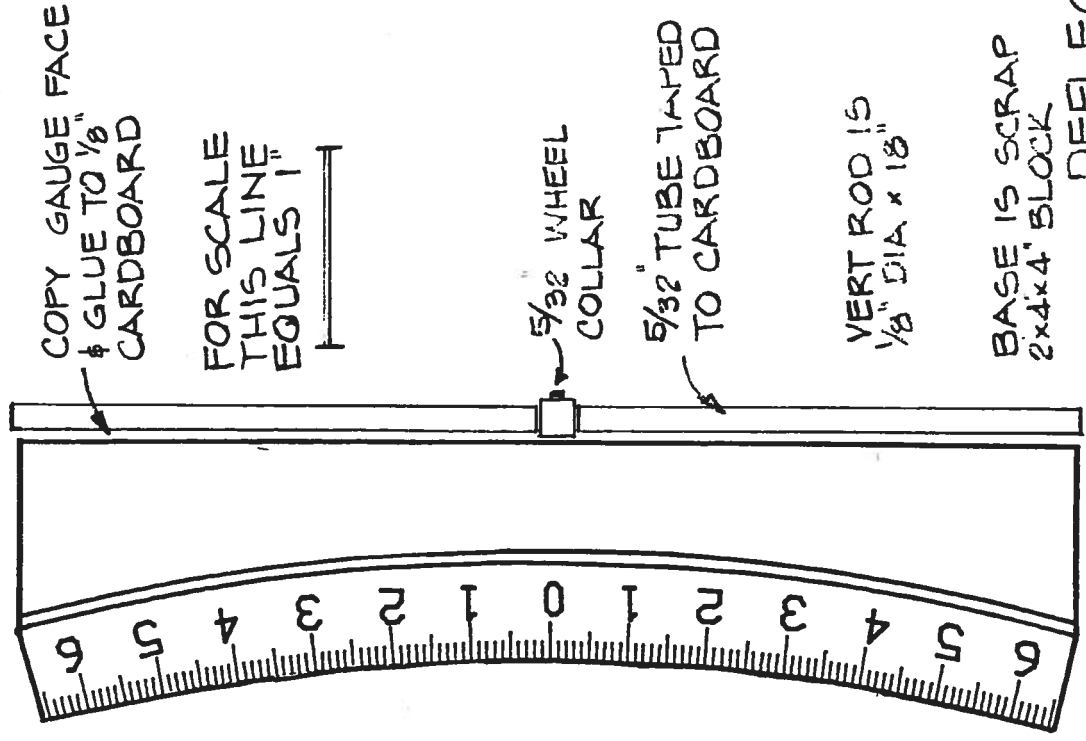
The little gadget we've shown is an in-shop surface deflector gauge. This is an absolute must for beginning the trimming process of your airplane. *It's very important that all complementing flying surfaces deflect equally.* For instance, the right aileron must deflect the same amount as the left aileron, given a specific transmitter input and assuming no differential.

The elevator halves must also deflect the same amount or you'll impart a corkscrew to your loops. To determine that the surfaces are equal goes beyond just measuring the distance of the control horn from the control surface. In fact, we've found that when the control surface deflections are equal, using a gauge as shown, the measurements of the control horns from the flying surfaces are different. Therefore, do not go by measurements or your eyeball. Either build a pair of these as outlined or buy a deflection gauge. The important issue is to use the instrument.

The idea of this gauge is to magnify the movement of the surfaces to determine if they are equal. If the surface throws are equal with the extenders, you can be assured that the actual surfaces are deflecting the same amount.

To use the deflection gauge, first make sure your surface throws are set at maximum. Do not impart any dual rates into the system at this time; leave that until later. Then, using tape, attach a mixing stick to the control surface. Next, place the deflection gauges the same distance from the hinge lines. Now impart surface throws with your transmitter and determine if the complementing surfaces are deflecting equally. If they are different, then either screw the horn in or out, depending upon what is necessary.

This is your first step and one of the most important steps in trimming your airplane. If your surfaces are not deflecting equally then you will be trimming your airplane for many more flights than necessary.

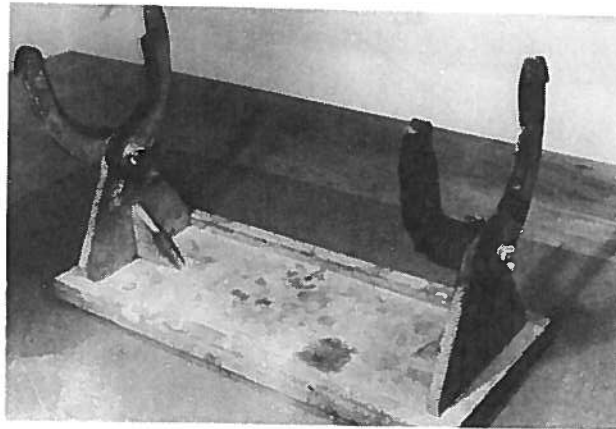


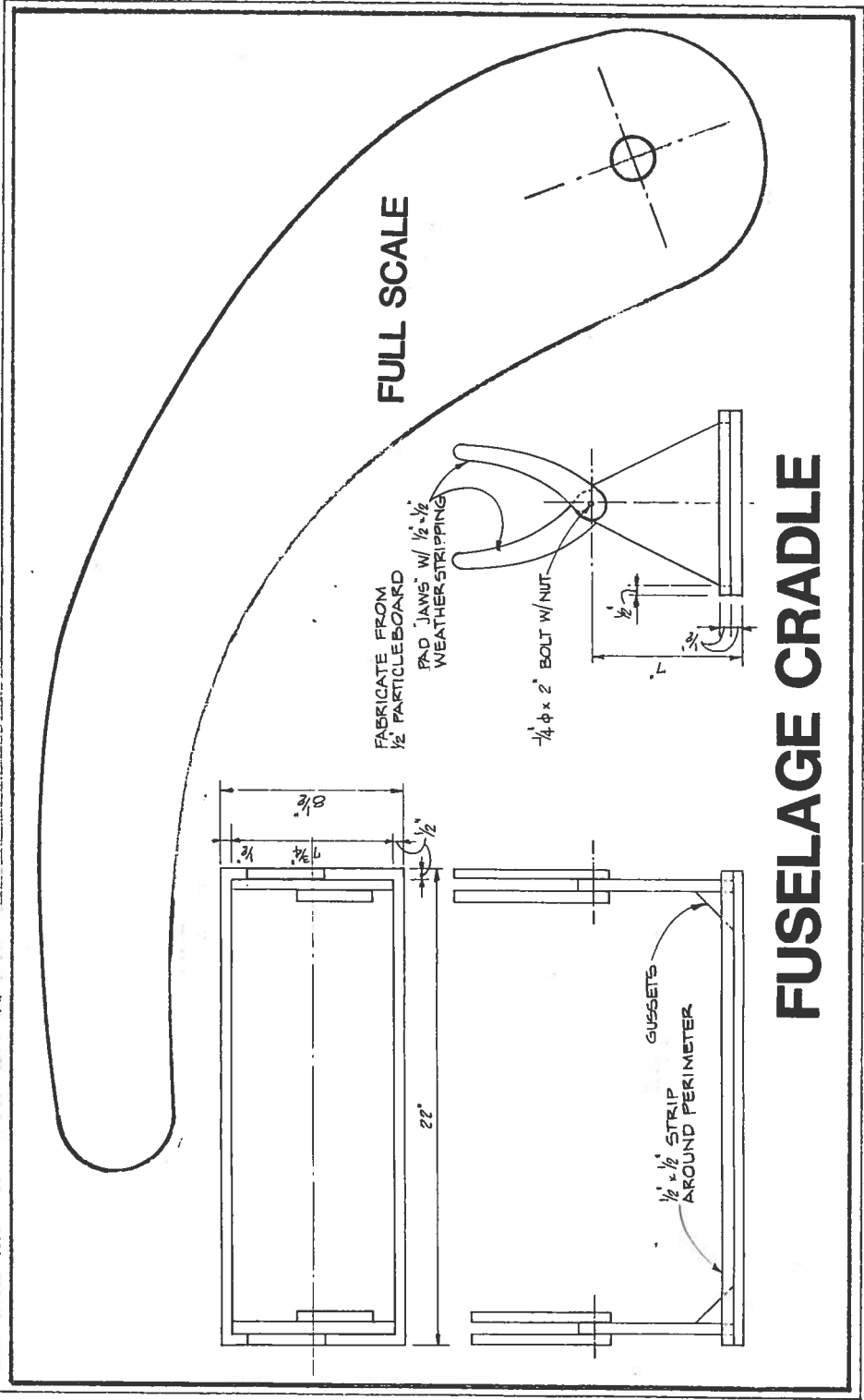
DEFLECTION GAUGE

## FUSELAGE VICE

During our early years of modeling, we were faced with the problem of holding the fuselage securely while either sanding it, aligning it with the wing and stab, installing the radio, or performing general maintenance. We tried to use foam cradles but found they wouldn't hold the fuselage securely without taping it in the desired position. This was cumbersome and frustrating. We were at a friend's house preparing a fuselage for priming when he dragged out this wonderful stand.

We were so intrigued with how it worked and the support it gave the fuselage that we built two of them. We find it's one of the handiest tools in the shop and believe that others could use it as well. It's very versatile. The jaws rotate and conform to the sides of the fuselage, and can hold the fuselage either upright, upside down or at any angle you need. Give it a try; and we think you'll be pleased with the results.





## SMARTTOOL™ INCIDENCE METER

When it came time to set the incidence angles for the wing and stabs of our pattern airplanes, we were left to the mercy of a Robart Incidence Meter. The Robart meter is a good instrument, but we were striving for more accuracy than that meter is capable of delivering. Nothing is more frustrating than trying to determine if you have .5 degrees or .25 degrees on a Robart Incidence Meter (with old, failing eyesight). That's when we ran across an article in *Model Airplane News* using a "Smart Level" combined with the Robart Incidence meter bar and clamps. We built an instrument similar to the one shown in the magazine. Our success with this device has been nothing short of fantastic. However, the "Smart Level" is no longer available. Now Macklanberg-Duncan manufactures a level known as the Smarttool™. It is a level with a built-in electronic leveling module. The level can be used in conjunction with the alignment jig in Chapter 13. But if you want to use the alignment process we outlined in Chapter 6 you'll need a true incidence meter. We have devised a way of attaching the leveling module of the Smarttool™ to the Robart Incidence meter bars and clamps. Anyone wanting great accuracy in their wing and stab incidence would be well-advised to build one of these great gadgets.

The Smarttool™ electronic leveling device is calibrated to the tenths of degrees. Over the length of this hybrid incidence meter, a tenth of a degree is a little thicker than a piece of paper. Yet, cost is a drawback to this instrument.

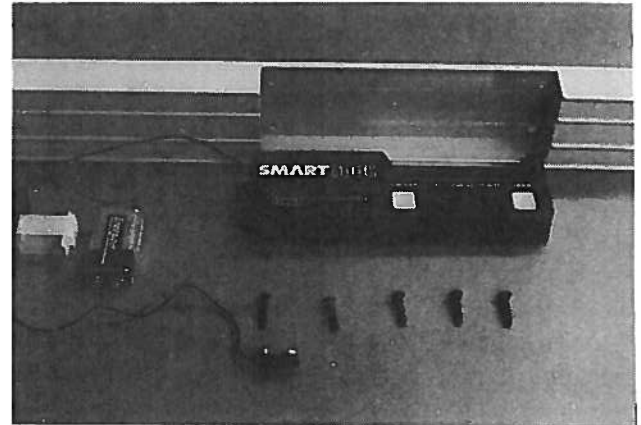
The cost of the Smarttool™ is \$100.00, but it serves not only as a part of the incidence meter but also as a great level! You will also need two Robart Incidence Meters for the bar supports and clamps. Combining the Robart components and the Smarttool™ pushes the cost of this instrument to almost \$200.

Fortunately, this hybrid incidence meter doesn't weigh much more than a Robart incidence

meter. That was one drawback to the earlier version of this hybrid incidence meter.

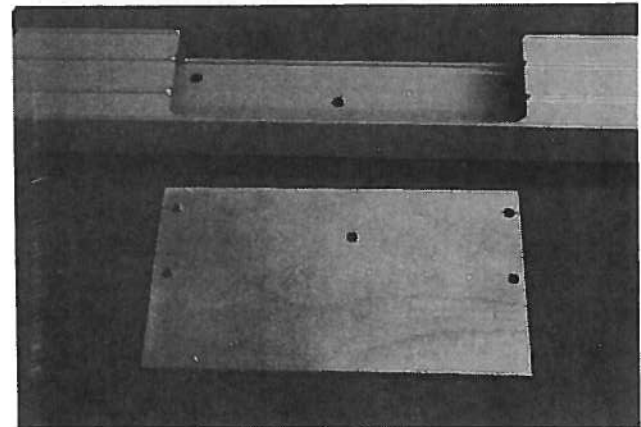
Included are pictures and instructions on how to construct the instrument.

**15.14.** Disconnect and remove the battery from the end of the Smarttool™. Unscrew the electronic module from the Smarttool™.



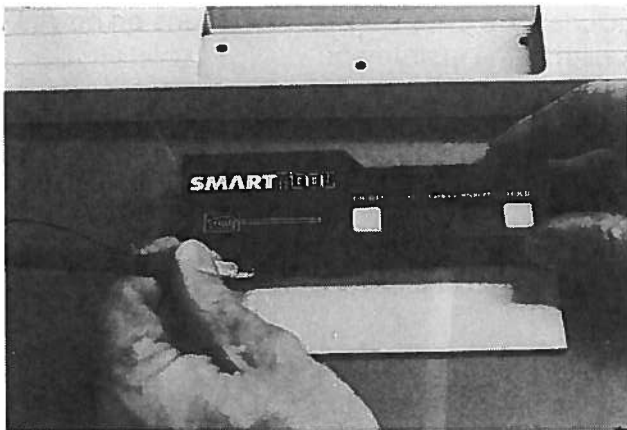
Electronic Module And Battery Removed From Smarttool™

**15.15.** Cut a piece of 1/8" construction grade plywood approximately 4-5/8"x2-3/4". Using the level housing as a template, mark the hole locations on the piece of plywood. Drill 3/16" holes in the plywood at the hole locations.



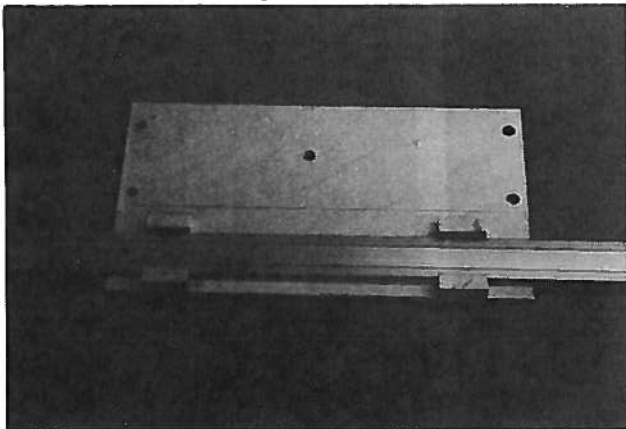
Plywood With Holes Drilled For Electronic Module

**15.16.** Screw the electronic module to the plywood and draw a line along the base of the module.



Base Line Of Electronic Module Established

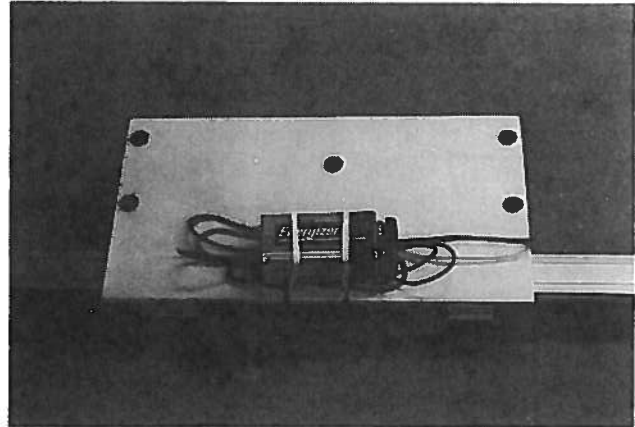
**15.17.** Remove the electronic module from the plywood piece. Measure down from the base line approximately 1-1/2" and draw a line. Cut 4 pieces of 1/4" plywood to 1/4"x3/4". Glue two pieces of 1/4"x1/4"x3/4" plywood on the lower line. Place the Robart Incidence Meter Bar against the two plywood pieces and glue the other two 1/4"x1/4"x3/4" pieces of plywood above the other two and against the bar.



Attaching Supports For The Support Bars

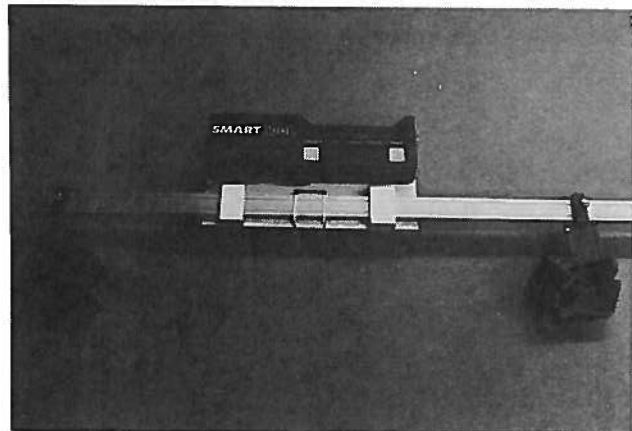
**15.18.** With the support bars in place, sand the four support pieces flush with the top of the bars. Glue two pieces of 1/8"x3/4"x1-1/4" plywood over the tops of the four plywood supports.

**15.19.** Cut grooves in the plywood support piece to support the battery and wires for the electronic module. Install and connect the battery.



Battery Installed On Back Of Incidence Meter

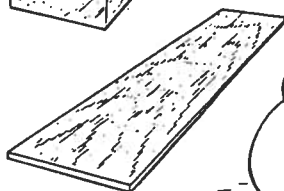
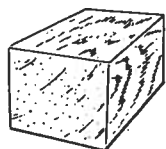
**15.20.** Level the instrument as per the instructions included with the Smarttool™. Your hybrid incidence meter is complete!



Complete Hybrid Incidence Meter

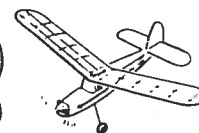
## **APPENDIX A Balsa Wood**





# Interesting Facts About **BALSA WOOD**

*For modelers who want to build light*



Model airplanes are no different than any other type of flying machine, large or small - **THE LIGHTER IT IS BUILT, THE BETTER IT WILL FLY!** With that in mind, it is easy to understand why balsa wood has been the standard material for model airplane construction since it first became readily available in the U.S. in the late 1920s. Its outstanding strength-to-weight ratio enables hobbyists to construct durable models that fly in a totally realistic manner. Balsa also absorbs shock and vibration well and can be easily cut, shaped, and glued with simple hand tools.

**WHERE DOES BALSA WOOD COME FROM?** Balsa trees grow naturally in the humid rain forests of Central and South America. Its natural range extends south from Guatemala, through Central America, to the north and west coast of South America as far as Bolivia. However, the small country of Ecuador, on the western coast of South America, is the primary source of model aircraft grade balsa in the world. Balsa needs a warm climate with plenty of rainfall and good drainage. For that reason, the best stands of balsa usually appear on the high ground between tropical rivers. Ecuador has the ideal geography and climate for growing balsa trees. The scientific name for balsa wood is *ochroma lagopus*. The word balsa itself is Spanish meaning *raft*, in reference to its excellent floatation qualities. In Ecuador it is known as *Boya*, meaning *buoy*.

**HOW DOES BALSA WOOD GROW?** There is no such thing as entire forests of balsa trees. They grow singly or in very small, widely scattered groups in the jungle. For hundreds of years, balsa was actually considered a weed tree. They reproduce by growing hundreds of long seed pods, which eventually open up and, with the help of the wind, scatter thousands of new seeds over a large area of the jungle. Each seed is airborne on its own small wisp of down, similar to the way dandelion seeds spread. The seeds eventually fall to the ground and are covered by the litter of the jungle. There they lay and accumulate until one day there is an opening in the jungle canopy large enough for the sun's rays to strike the jungle floor and start the seeds growing. Wherever there was an opening, made either by a farmer or by another tree dying, balsa will spring up as thick as grass. A farmer is often hard put to keep his food plot clear of balsa. As the new balsa trees grow, the strongest will become predominate and the weaker trees will die. By the time they are mature, there may be only one or two balsa trees to an acre of jungle.

**HOW LONG DOES IT TAKE A BALSA TREE TO GROW?** Balsa trees grow very rapidly (like all pesky weeds). Six months after germination, the tree is about 1-1/2 inches in diameter and 10 - 12 feet tall! In 6 to 10 years the tree is ready for cutting, having reached a height of 60 to 90 feet tall and a diameter of 12 to 45 inches. If left to continue growing, the new wood being grown on the outside layers becomes very hard and the tree begins to rot in the center. Unharvested, a balsa tree may grow to a diameter of 6 feet or more, but very little usable lumber can be obtained from a tree of this size. The balsa leaf is similar in shape to a grape leaf, only a lot bigger. When the tree is young, these leaves measure as much as four feet across. They become progressively smaller as the tree grows older, until they are about 8 - 10 inches across. Balsa is one of the few trees in the jungle which has a simple leaf shape. This fact alone makes the balsa tree stand out in the jungle.

**THE PERFECT NURSE!** Nature evidently designed the balsa tree to be a "nurse tree" which would protect the slower-growing species of trees from the scorching jungle sun during their critical early years. For instance, in an area of the jungle that has been ravaged by a tropical

storm or other natural disaster, the balsa trees will quickly sprout and begin to shoot up to impressive heights in a very short time. Their fast growth, and the extra large leaves they have in their early years, provide shade to the young seedlings of the slower-growing forest giants. By the time the seedlings are established enough to take care of themselves, the balsa tree is beginning to die. Undoubtedly, the balsa tree's rapid growth, fast spreading crown of first very large and gradually smaller leaves, and it's relatively short life span were intended to make it the "perfect nurse" in the jungle ecosystem.

**HOW ARE BALSA TREES HARVESTED?** While nature intended the balsa tree to be a short lived nursemaid, mankind eventually discovered that it was an extremely useful resource. The real start of the balsa business was during World War I, when the allies were in need of a plentiful substitute for cork. The only drawback to using balsa was, and still is, the back breaking work that is necessary to get it out of the jungle. Because of the way the individual balsa trees are scattered throughout the jungles, it has never been possible to use mass production logging procedures and equipment. The best way to log balsa trees is to go back to the methods of Paul Bunyan — chop them down with an axe, haul them to the nearest river by ox team, tie them together into rafts, and then float the rafts of balsa logs down the river to the saw mill. The logging team usually consists of two native Ecuadorians, each armed with a broad Spanish axe, a machete, and a long pole sharpened like a chisel on one end for removing the bark from the downed trees. Because of the hilly terrain, an ox team may only be able to drag two logs to the river per day. At the saw mill the raw balsa is first rough cut into large boards, then carefully kiln dried, and finally packed into bales for shipment to the U.S. via ocean freighter. Final cutting and finishing of our model aircraft balsa is done right here at the SIG factory. As a result of the balsa tree's fast growth cycle, both the quality and lightness of the lumber obtained from a balsa tree can vary enormously depending upon the tree's age at the time of cutting.



**SIG**

**THE MOST FAMOUS NAME IN BALSA!**

**WHY IS BALSA WOOD SO LIGHT?** The secret to balsa wood's lightness can only be seen with a microscope. The cells are big and very thin walled, so that the ratio of solid matter to open space is as small as possible. Most woods have gobs of heavy, plastic-like cement, called lignin, holding the cells together. In balsa, lignin is at a minimum. Only about 40% of the volume of a piece of balsa is solid substance. To give a balsa tree the strength it needs to stand in the jungle, nature pumps each balsa cell full of water until they become rigid - like a car tire full of air. Green balsa wood typically contains five times as much water by weight as it has actual wood substance, compared to most hardwoods which contain very little water in relation to wood substance. Green balsa wood must therefore be carefully kiln dried to remove most of the water before it can be sold. Kiln drying is a tedious two week process that carefully removes the excess water until the moisture content is only 6%. Kiln drying also kills any bacteria, fungi, and insects that may have been in the raw balsa wood.

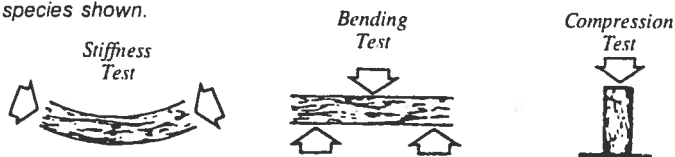
**HOW LIGHT IS KILN DRIED BALSA WOOD?** Finished balsa wood, like you find in model airplane kits, varies widely in weight. Balsa is occasionally found weighing as little as 4 lbs. per cu. ft. On the other hand, you can also find balsa which will weigh 24 lbs. or more per cu. ft. However, the general run of commercial balsa for model airplanes will weigh between 6 pounds to 18 lbs. per cu. ft. Eight to twelve pound balsa is considered medium or average weight, and is the most plentiful. Six pound or less is considered "contest grade", which is very rare and sometimes even impossible to obtain.

**IS BALSA THE LIGHTEST WOOD IN THE WORLD?** No! Most people are surprised to hear that botanically, balsa wood is only about the third or fourth lightest wood in the world. However, all the woods which are lighter than balsa are terribly weak and unsuitable for any practical use. The very lightest varieties don't really resemble wood at all, as we commonly think of it, but are more like a tree-like vegetable that grows in rings, similar in texture to an onion. It is not until balsa is reached that there is any sign of real strength combined with lightness. In fact, balsa wood is often considered the strongest wood for its weight in the world. Pound for pound it is stronger in some respects than pine, hickory, or even oak (see chart below).

#### STRENGTH OF BALSA WOOD COMPARED TO OTHER WOODS

Species	Weight Lbs./Cu. Ft.	Stiffness Strength	Bending Strength	Compression Strength
BALSA	8	72	70	75
BALSA	10	100	100	100
BALSA	14	156	161	149
SPRUCE	28	230	260	289
YELLOW PINE	28	222	277	288
DOUGLAS FIR	30	241	291	341
HICKORY	50	379	638	514
OAK	48	295	430	366
BASSWOOD	26	261	288	288
BLACK WALNUT	37	301	506	512

**NOTE ABOUT CHART:** The strength of balsa varies in direct relation to its density or weight - the heavier the wood, the stronger it is. The above chart was designed with 10 lb./cu. ft. balsa as the median. In other words, balsa at 10 lbs./cu. ft. has been tested given a value of 100. The other woods were then tested in the same way and given a figure that is numerically in proportion. By comparing the relative strength figures in the chart, it will be seen that balsa is as strong or stronger, pound for pound, than most of the species shown.



**SELECTING BALSA FOR MODEL BUILDING:** Most hobby shops have a large rack of balsa sheets, sticks, and blocks that you can choose from if you are going to build a model airplane from scratch. Undoubtedly, because of the nature of balsa, the actual weight of each piece

of wood of the same size can vary slightly. When you select the pieces you want to buy, you should keep their final use in mind. Logically one should select the lightest grades for the lightly stressed model parts (nose blocks, wingtip blocks, fill-ins, etc.), and the heavier grades for important load bearing parts of the structure (spars, fuselage stringers, etc.). To a large extent, this selection is already partly done for you. Here at SIG, we purposely cut up our lightest raw balsa into blocks, and our hardest raw balsa into sticks. Sheets are cut in the entire wide range of density.

To give you an idea how much common sizes of balsa can vary in weight depending upon the density of raw stock it was cut from, the following three charts have been developed. They show the actual weight in ounces of each size piece when it is cut from 6, 8, 10, 12, 14, or 18 lb./cu. ft. stock. For example, in the first chart for BALSA SHEETS we see that a 1/16" x 3" x 36" sheet cut from 10 lb./cu. ft. stock will weigh approximately .625 ounces. The same size sheet cut from 14 lb./cu. ft. stock will weigh about .875 ounces.

#### BALSA SHEETS weight is in ounces

SIZE 36"x	STOCK DENSITY POUNDS PER CUBIC FOOT					
	6	8	10	12	14	16
1/32" x 2"	.125	.167	.271	.250	.291	.333
	.1875	.250	.3125	.375	.4375	.500
	.250	.333	.417	.500	.583	.667
1/16" x 2"	.250	.333	.417	.500	.583	.667
	.375	.500	.625	.750	.875	1.000
	.500	.667	.833	1.000	1.167	1.333
3/32" x 2"	.375	.500	.625	.750	.875	1.000
	.5625	.750	.9375	1.125	1.3125	1.500
	.750	1.000	1.250	1.500	1.750	2.000
1/8" x 2"	.500	.667	.833	1.000	1.167	1.333
	.750	1.000	1.250	1.500	1.750	2.000
	1.000	1.333	1.667	2.000	2.333	2.667
3/16" x 2"	.750	1.000	1.250	1.500	1.750	2.000
	1.125	1.500	1.875	2.250	2.625	3.000
	1.500	2.000	2.500	3.000	3.500	4.000
1/4" x 2"	1.000	1.333	1.667	2.000	2.333	2.667
	1.500	2.000	2.500	3.000	3.500	4.000
	2.000	2.667	3.333	4.000	4.667	5.333
3/8" x 2"	1.500	2.000	2.500	3.000	3.500	4.000
	2.250	3.000	3.750	4.500	5.250	6.000
	3.000	4.000	5.000	6.000	7.000	8.000
1/2" x 2"	2.000	2.667	3.333	4.000	4.667	5.333
	3.000	4.000	5.000	6.000	7.000	8.000
	4.000	5.333	6.667	8.000	9.333	10.667

#### BALSA BLOCKS weight is in ounces

SIZE 36"x	STOCK DENSITY POUNDS PER CUBIC FOOT					
	6	8	10	12	14	16
1" x 1"	2.0	2.667	3.333	4.0	4.667	5.333
	3.0	4.0	5.0	6.0	7.0	8.0
	4.0	5.333	6.667	8.0	9.333	10.667
	5.0	6.667	8.333	10.0	11.667	13.333
1 1/2" x 1 1/2"	4.5	6.0	7.5	9.0	10.5	12.0
	6.0	8.0	10.0	12.0	14.0	16.0
	7.5	10.0	12.5	15.0	17.5	20.0
	9.0	12.0	15.0	18.0	21.0	24.0
2" x 2"	8.0	10.667	13.333	16.0	18.667	21.333
	10.0	13.333	16.667	20.0	23.333	26.667
	12.0	16.0	20.0	24.0	28.0	32.0
	14.0	18.667	23.333	28.0	33.333	38.667
2 1/2" x 2 1/2"	12.5	16.667	20.833	25.0	29.167	33.333
	15.0	20.0	25.0	30.0	35.0	40.0
	18.0	24.0	30.0	36.0	42.0	48.0
	24.0	32.0	40.0	48.0	56.0	64.0

## BALSA STICKS

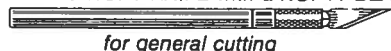
weight is in ounces

SIZE 3/64" x	No. OF STRIPS	STOCK DENSITY POUNDS PER CUBIC FOOT					
		6	8	10	12	14	16
1/16" x 1/16"	16	.125	.167	.208	.250	.292	.333
	8	.188	.250	.312	.375	.438	.500
	4	.125	.167	.208	.250	.292	.333
	2	.188	.250	.312	.375	.438	.500
	1	.125	.167	.208	.250	.292	.333
	1/2	.188	.250	.312	.375	.438	.500
3/32" x 3/32"	8	.141	.188	.234	.281	.328	.375
	4	.188	.250	.312	.375	.438	.500
	2	.141	.188	.234	.281	.328	.375
	1	.188	.250	.312	.375	.438	.500
	1/2	.141	.188	.234	.281	.328	.375
	1/4	.188	.250	.312	.375	.438	.500
1/8" x 1/8"	4	.125	.167	.208	.250	.292	.333
	2	.188	.250	.312	.375	.438	.500
	1	.125	.167	.208	.250	.292	.333
	1/2	.188	.250	.312	.375	.438	.500
	1/4	.125	.167	.208	.250	.292	.333
	1/8	.188	.250	.312	.375	.438	.500
3/16" x 3/16"	2	.141	.188	.234	.281	.328	.375
	1	.188	.250	.312	.375	.438	.500
	1/2	.141	.188	.234	.281	.328	.375
	1/4	.188	.250	.312	.375	.438	.500
	1/8	.141	.188	.234	.281	.328	.375
	1/4	.188	.250	.312	.375	.438	.500
1/4" x 1/4"	1	.125	.167	.208	.250	.292	.333
	1/2	.188	.250	.312	.375	.438	.500
	1/4	.125	.167	.208	.250	.292	.333
	1/8	.188	.250	.312	.375	.438	.500
	1/4	.125	.167	.208	.250	.292	.333
	1/8	.188	.250	.312	.375	.438	.500
3/8" x 3/8"	1	.281	.375	.469	.563	.656	.750
	1/2	.375	.500	.625	.750	.876	1.000
	1/4	.281	.375	.469	.563	.656	.750
	1/8	.375	.500	.625	.750	.876	1.000
	1/4	.281	.375	.469	.563	.656	.750
	1/8	.375	.500	.625	.750	.876	1.000
1/2" x 1/2"	1	.500	.667	.832	1.000	1.166	1.333
	1/2	.500	.667	.832	1.000	1.166	1.333
	1/4	.500	.667	.832	1.000	1.166	1.333
	1/8	.500	.667	.832	1.000	1.166	1.333
	1/4	.500	.667	.832	1.000	1.166	1.333
	1/8	.500	.667	.832	1.000	1.166	1.333
3/4" x 3/4"	1	1.125	1.500	1.875	2.250	2.625	3.000
	1/2	1.125	1.500	1.875	2.250	2.625	3.000
	1/4	1.125	1.500	1.875	2.250	2.625	3.000
	1/8	1.125	1.500	1.875	2.250	2.625	3.000
	1/4	1.125	1.500	1.875	2.250	2.625	3.000
	1/8	1.125	1.500	1.875	2.250	2.625	3.000

### COMMON MODELER'S TOOLS FOR CUTTING AND SHAPING BALSA WOOD:

Balsa is a very "friendly" wood to work with — so light, so soft, so easily worked into so many things. You don't need heavy-duty power saws and sanders like you would if working with a hardwood. In fact, even with an extensive power shop at their disposal, the professional model builders here at the SIG factory find that they still rely primarily on 4 or 5 simple hand tools for the majority of their work. If you are just starting out in the model airplane hobby, here are the tools that they recommend that you get:

X-ACTO NO. 1 KNIFE with a NO. 11 BLADE

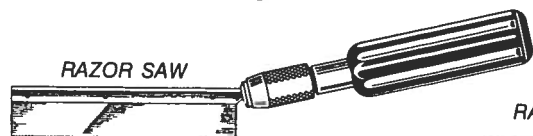


for general cutting

X-ACTO NO. 2 KNIFE with a NO. 26 BLADE



for carving



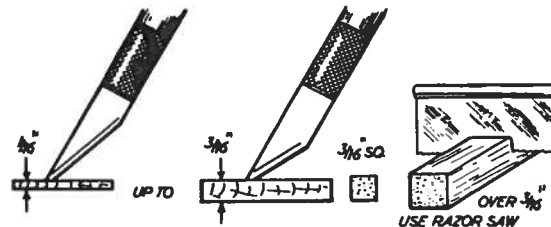
for cutting thick sizes of wood



RAZOR PLANE

for shaping

A knife or razor blade will work well for cutting balsa sheets and sticks up to 3/16" thick. Use a razor saw for sizes over thicker than 3/16". Always keep replacement blades on hand — blades do wear out and a dull blade can make it impossible to do a good job.

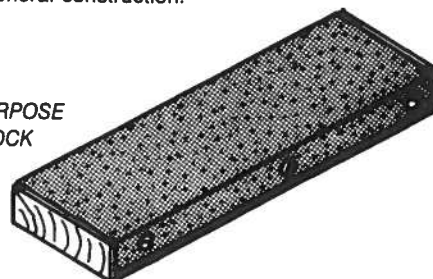


### GENERAL CUTTING GUIDELINES

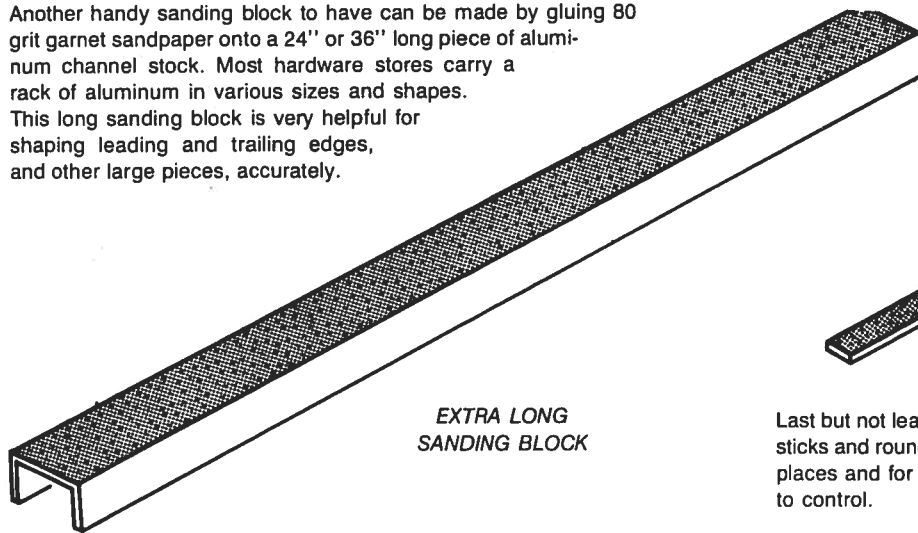
RIGHT!	TYPE OF CUTTING	WRONG!
	<b>CUTTING STICKS</b> USE SHARP KNIFE OR RAZOR BLADE TO CHOP OFF SMALL SIZES - USE RAZOR SAW FOR LARGER SIZES.	 KNIFE WILL CRUSH
	<b>STRAIGHT CUTS WITH THE GRAIN</b> USE METAL RULER AS A GUIDE — CUT IN DIRECTION THAT GRAIN PULLS BLADE AGAINST STRAIGHTEDGE	 BLADE WILL RUN OFF LINE
	<b>STRAIGHT CUTS IN THICK SHEETS</b> USE A RAZOR SAW — ALWAYS MAKE EDGE TO EDGE CUTS ACROSS THE FLAT SHEET	 WILL TEAR OR SPLIT
	<b>CUTTING FREEHAND CURVES</b> CUT IN DIRECTION WHERE GRAIN WILL PULL BLADE AWAY FROM SHAPE — CLEAN UP LATER AS NECESSARY WITH KNIFE AND SANDPAPER BLOCK	 BLADE RUNS INSIDE OUTLINE
	<b>CROSS GRAIN KNIFE CUTS</b> ALWAYS CUT FROM EDGE TOWARDS CENTER — NEVER OUTWARDS TO AN EDGE	 EDGE WILL TEAR
	<b>FOR CUTTING BLOCKS</b> USE A STIFF BACK SAW AS FAR AS POSSIBLE — CUT IN FROM BOTH SIDES	 WILL NOT CUT SQUARE

**YOU WILL ALSO NEED SANDING BLOCKS:** In addition to the cutting tools, you will need an assortment of different size sanding blocks. These are indispensable tools for model construction. You can buy ready-made sanding blocks or make your own. The most often used general-purpose sanding block in our model shop is made simply by wrapping a full 9" x 11" sheet of sandpaper around a 3/4" x 3" x 11" hardwood or plywood block. Use three screws along one edge to hold the overlapped ends of the sandpaper in place. Use 80 grit garnet sandpaper on the block during general construction.

GENERAL PURPOSE  
SANDING BLOCK



Another handy sanding block to have can be made by gluing 80 grit garnet sandpaper onto a 24" or 36" long piece of aluminum channel stock. Most hardware stores carry a rack of aluminum in various sizes and shapes. This long sanding block is very helpful for shaping leading and trailing edges, and other large pieces, accurately.



EXTRA LONG  
SANDING BLOCK

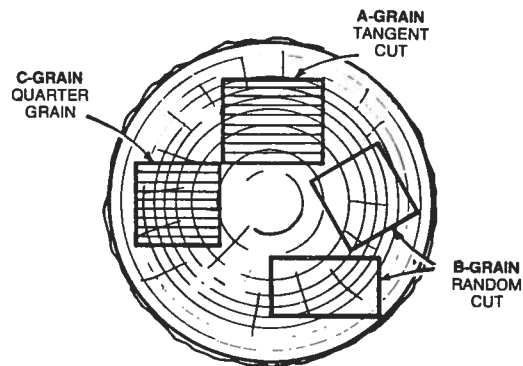
SMALL SANDPAPER "FILES"



Last but not least, glue sandpaper onto different sizes of scrap plywood sticks and round hardwood dowels. These are handy for working in tight places and for careful shaping where a big sanding block is too hard to control.

## BALSA GRAIN ID. CHART - LEARN HOW TO IDENTIFY ALL THREE GRAIN TYPES

In selecting balsa sheets for use in your model, it is important to consider the way the grain runs through the sheet as well as the weight of the sheet. The grain direction actually controls the rigidity or flexibility of a balsa sheet more than the density does. For example, if the sheet is cut from the log so that the tree's annular rings run across the thickness of the sheet (A-grain, tangent cut), then the sheet will be fairly flexible edge to edge. In fact, after soaking in water some tangent cut sheets can be completely rolled into a tube shape without splitting. If on the other hand the sheet is cut with the annular rings running through the thickness of the sheet (C-grain, quarter grain), the sheet will be very rigid edge to edge and cannot be bent without splitting. When the grain direction is less clearly defined (B-grain, random cut), the sheet will have intermediate properties between A and C grain. Naturally, B-grain is the most common and is suitable for most jobs. The point to bear in mind is that whenever you come across pure A-grain or C-grain sheets, learn where to use them to take best advantage of their special characteristics. The following chart illustrates the 3 basic grain types for sheet balsa and lists the most appropriate uses for each.



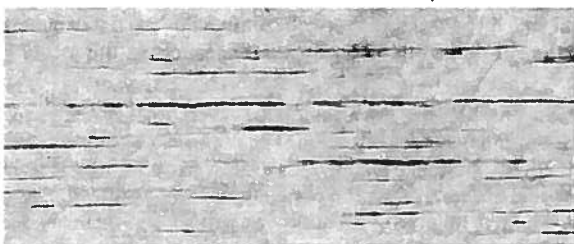
CROSS-SECTION OF BALSA LOG



**A-GRAIN** sheet balsa has long fibers that show up as long grain lines. It is very flexible across the sheet and bends around curves easily. Also warps easily. Sometimes called "tangent cut".

**DO:** Use for sheet covering rounded fuselages and wing leading edges, planking fuselages, forming tubes, strong flexible spars, HL glider fuselages.

**DON'T:** Use for sheet balsa wings or tail surfaces, flat fuselage sides, ribs, or formers.



**B-GRAIN** sheet balsa has some of the qualities of both type A and type C. Grain lines are shorter than type A, and it feels stiffer across the sheet. It is a general purpose sheet and can be used for many jobs. Sometimes called "random cut".

**DO:** Use for flat fuselage sides, trailing edges, wing ribs, formers, planking gradual curves, wing leading edge sheeting.

**DON'T:** Use where type A or type C will do a significantly better job.



**C-GRAIN** sheet balsa has a beautiful mottled appearance. It is very stiff across the sheet and splits easily. But when used properly, it helps to build the lightest, strongest models. Most warp resistant type. Sometimes called "quarter grain".

**DO:** Use for sheet balsa wings and tails, flat fuselage sides, wing ribs, formers, trailing edges. Best type for HL glider wings and tails.

**DON'T:** Use for curved planking, rounded fuselages, round tubes, HL glider fuselages, or wing spars.

WEIGHT OF COMMON BALSA SHAPES  
(IN GRAMS)

	CUBIC INCHES	LIGHT			MEDIUM			HEAVY			
		#/CF 3	#/CF 4	#/CF 5	#/CF 6	#/CF 7	#/CF 8	#/CF 9	#/CF 10	#/CF 11	#/CF 12
SHEETING											
1/16"x3"x24"	4.50	3.5	4.7	5.9	7.1	8.3	9.5	10.6	11.8	13.0	14.2
1/16"x3"x36"	6.75	5.3	7.1	8.9	10.6	12.4	14.2	15.9	17.7	19.5	21.3
1/16"x4"x24"	6.00	4.7	6.3	7.9	9.5	11.0	12.6	14.2	15.8	17.3	18.9
1/16"x4"x36"	9.00	7.1	9.5	11.8	14.2	16.5	18.9	21.3	23.6	26.0	28.4
3/32"x3"x24"	6.75	5.3	7.1	8.9	10.6	12.4	14.2	15.9	17.7	19.5	21.3
3/32"x3"x36"	10.13	8.0	10.6	13.3	16.0	18.6	21.3	23.9	26.6	29.3	31.9
3/32"x4"x24"	9.00	7.1	9.5	11.8	14.2	16.5	18.9	21.3	23.6	26.0	28.4
3/32"x4"x36"	13.50	10.6	14.2	17.7	21.3	24.8	28.4	31.9	35.4	39.0	42.5
1/8"x3"x24"	9.00	7.1	9.5	11.8	14.2	16.5	18.9	21.3	23.6	26.0	28.4
1/8"x3"x36"	13.50	10.6	14.2	17.7	21.3	24.8	28.4	31.9	35.4	39.0	42.5
1/8"x4"x24"	12.00	9.5	12.6	15.8	18.9	22.1	25.2	28.4	31.5	34.7	37.8
1/8"x4"x36"	18.00	14.2	18.9	23.6	28.4	33.1	37.8	42.5	47.3	52.0	56.7
STICKS											
1/4"x1/4"x36"	2.25	1.8	2.4	3.0	3.5	4.1	4.7	5.3	5.9	6.5	7.1
1/4"x1/2"x36"	4.50	3.5	4.7	5.9	7.1	8.3	9.5	10.6	11.8	13.0	14.2
1/4"x3/4"x36"	6.75	5.3	7.1	8.9	10.6	12.4	14.2	15.9	17.7	19.5	21.3
1/4"x1"x36"	9.00	7.1	9.5	11.8	14.2	16.5	18.9	21.3	23.6	26.0	28.4
3/8"x3/8"x36"	5.06	4.0	5.3	6.6	8.0	9.3	10.6	12.0	13.3	14.6	15.9



# APPENDIX B TRIMMING CHART

NSRCA Newsletter K-FACTOR

MAY 1990

## TRIMMING CHART

By Mike Chipchase (Australia)

TO TEST FOR	TEST PROCEDURE	OBSERVATIONS	ADJUSTMENTS
1. Control neutrals	Fly model straight and level	Use the transmitter trims for hands off straight & level flight	Adjust clavises to center transmitter trims
2. Control throws	Fly model and apply full deflection of each control in turn	Check the response of each control	Aileron Hi-rate, 3 rolls in 4 seconds. Lo-rate, 3 rolls in 6 seconds. Elevator Hi-rate, to give a smooth square corner. Lo-rate, to give a loop of approx. 130 ft. dia. Rudder Hi-rate approx. 30-35 degrees, for stall turns. Lo-rate, to maintain knife edge flight.
3. Decalage	Power off vertical dive, cross wind (if any). Release controls when model vertical (elevator trim must be neutral).	A. Does the model continue straight down? B. Does the model start to pull out (nose up)? C. Does the model start to tuck in (nose down)?	A. No adjustment B. Reduce incidence C. Increase incidence
4. Center of Gravity	Method 1: Roll model into near vertically banked turn. Method 2: Roll model inverted.	A. Nose drops B. Tail drops A. Lots of down elevator required to maintain level flight B. No down elevator required to maintain level flight, or model climbs.	A. Add weight to tail B. Add weight to nose A. Add weight to tail B. Add weight to nose
5. Tip Weight (course adjustment)	Fly model straight and level upright. Check aileron trim maintains wing level. Roll model inverted, wings level. Release aileron stick.	A. Model does not drop a wing B. Left wing drops C. Right wing drops	A. No adjustment required B. Add weight to right tip C. Add weight to left tip
6. Side Thrust	Fly model away from you, into any wind. Pull it into a vertical climb (watch for deviations as it slows down).	A. Model continues straight up B. Model veers left C. Model veers right	A. No adjustment needed B. Add right thrust C. Reduce right thrust (move thrust line left)
7. Up/Down Thrust	Fly model on normal path into any wind. Parallel to strip, at a distance of around 100m from you (elevator trim should be neutral as per test No. 3). Pull it into a vertical climb & neutralize elevator.	A. Model continues straight up B. Model pitches up (goes towards top of model) C. Model pitches down (goes towards bottom model)	A. No adjustment needed B. Add down thrust C. Reduce down thrust
8. Tip Weight (fine adjustment)	Method 1: Fly the model as per test No. 6, and pull it into a reasonably small dia. inside loop (1 loop only). Method 2: Fly the model as per test No. 6. Push it down into an outside loop (1 loop only & fairly tight).	A. Model comes out with wings level B. Model comes out right wing low C. Model comes out left wing low A. Model comes out with wings level B. Model comes out with right wing low C. Model comes out with left wing low	A. No adjustment needed B. Add weight to left tip C. Add weight to right tip (or remove from left tip) A. No adjustment needed B. Add weight to left tip C. Add weight to right tip (or remove from left tip)
9. Aileron Differential	Method 1: Fly the model towards you, before it reaches you, pull it up into a vertical climb. Neutralize controls, then half roll the model. Method 2: Fly model on a normal pass and do 3 or more rolls.	A. No heading changes B. Heading change opposite to direction of roll command (ie. heading veers to models & your left after right roll) C. Heading change in direction of roll command A. Roll axis on model centerline B. Roll axis off to same side of model as roll command (ie. right roll, roll axis off right wing tip) C. Roll axis off to opposite side of model as roll command	A. Differential O.K. B. Increase differential C. Reduce differential A. Differential O.K. B. Increase differential C. Reduce differential
10. Dihedral	Fly model on normal pass and roll into knife-edge flight, maintain height with top rudder (do this test in both left & right knife-edge flight).	A. Model has no tendency to roll out of knife-edge flight B. Model rolls in direction of applied rudder C. Model rolls in opposite direction in both tests	A. Dihedral O.K. B. Reduce dihedral C. Increase dihedral
11. Elevator Alignment (for models with independent elevator halves)	Fly model as in test No. 6 and pull it up into an inside loop. Roll it inverted and repeat the above by pushing it up into an outside loop.	A. No rolling tendency when elevator applied. B. Model rolls in same direction in both tests C. Model rolls in opposite direction in both tests	A. Elevators in correct alignment B. Elevator halves misaligned. Either raise one half or lower the other. C. One elevator half has more throw than the other (model rolls to the side with the most throw). Reduce throw on one side, or increase throw on the other.
12. Pitching in knife-edge flight	Fly model as per test No. 10	A. There is no pitch up or down B. The nose pitches up (the model climbs laterally) C. Nose pitches down (model dives laterally)	A. No adjustment needed B. Alternate cures 1. Move the C.G. aft 2. Increase wing incidence 3. Add down trim to ailerons C. Reverse the above.

Notes: 1. Trimming must be done in calm conditions.  
2. Abbreviations are used above. 3. Make multiple tests before making adjustment. 4. If any changes are made, go back over previous steps and verify or readjust as necessary



## APPENDIX C PRODUCT DATA

If you should have trouble locating some of the equipment or item mentioned in this text, we have compiled the following list of manufacturers that you can contact to obtain their product.

### **Variac or Hot Wire Accessories:**

"KISS"

Sam Turner  
2716 Shadecrest Rd  
Land O'Lakes, FL 34639

Fistel Electronics Supply Co.  
1001 Bannock St.  
Denver, Colorado 80220  
(303) 629-1312

### **Gram Scale:**

Certified Balance Service  
7388 S. Revere Parkway  
Englewood, Colorado 80112  
(303) 799-0123

### **National Society Radio Controlled Aerobatics:**

Send Inquiries to:  
Academy of Model Aeronautics  
Attention: NSRCA  
P.O. Box 3028  
Muncie, IN 47307-1028

### **Motor Mounts:**

Hyde Custom Mounts  
1627 E. Palo Verde  
Yuma AZ 85365  
(602)344-1966

### **Miscellaneous Parts:**

Central Hobbies  
1401 Central Ave  
Billings, MT 59102  
(406) 259-9004

Radio South, Inc.  
5524 N. Palafox Hwy.  
Pensacola, FL 32503  
1-800-962-7802

Falcon Hobbies  
1-250-652-0554

### **Balsa Wood**

Lone Star Balsa  
Rt. 9, Box 437  
Lubbock Texas 79423  
1-800-687-5555

### **Fiberglass Kit Manufacturers**

Aero Lite Products  
23856 Dutch Lane  
Lutz, FL 33549  
(813) 949 0140

Aero Sport Products  
1066 Milford Drive  
Pickerington, OH 43147  
(614) 837-7058

Dick Hanson Models  
5269 Lucky Clover Ln.  
Murray, UT 84123  
(801) 261-1402

Dixie Competition Products  
6241 Phillippi Rd  
Julian, NC 27283  
(336) 685-9606

Honeycomposites, Inc.  
12974 S.W. 132 Ave.  
Miami, FL 33186  
(305) 233-4338

K & A Models  
669 Rock Creek Dr.  
Aurora, OH 44202  
(330) 562-7916

Precision Aero Composites  
Rt.4, Box 196  
Corinth, MS 38834-9436  
(601) 462-5480

### **All Balsa Airplane Plans & Parts**

Gator R/C Products, Inc.  
2100 N. Old Mill Road  
Brookline Station, MO 65619  
(417) 725-7755

### **YS Engine Parts**

Bayou Products  
1-504-242-7558

### **Building Components & Hardware:**

Precision Model Products  
14423 Hix St.  
Livonia, MI 48154  
(313)464-8594

### **Glow Fuel:**

Magnum Fuels  
1400 W. 70 th Ave  
Denver, Colorado,  
1-800-700-FUEL

### **Other Instructional Material:**

Two instructional videos on alignment and  
building techniques  
Robin's View Productions  
P.O. Box 68  
Stockertown, PA 18083  
(610) 746-0106

An instructional video on constructing removable  
horizontal stabilizers.

Sam Turner  
2716 Shadecrest Rd  
Land O'Lakes, FL 34639  
(813) 996-6421

### **Websites:**

Here are a few websites that will get you started.  
These are oriented towards building. Virtually  
every one of them will link you to other websites  
and more addresses just cascades from there.  
Enjoy them. You can spend as much time on the  
computer as you can building your airplane.

Sam Turners:  
<http://members.aol.com/s1turner/index.html>

Prarie Patttern Page:  
<http://home.kscable.com/ppp/>

NSRCA:  
<http://www.wtp.net/DBEST/patternpage.html>

AMA:  
<http://www.modelaircraft.org/>

Colorado RC Pattern:  
<http://www.pcisys.net/~tnewman/patrn.html>

Texas Pattern Page:  
<http://MCIA.com/~donramsey>

## APPENDIX D ABOUT THE AUTHORS

Bruce Thompson and Don Atwood have been involved in radio-controlled modeling for many years. Both have built and flown numerous pattern airplanes. They have accumulated a number of building techniques through their own trial and error methods or by word of mouth from other flyers. The techniques they recommend have been tried and used on numerous occasions on their own airplanes.



Bruce began modeling when he was twelve years old. He began by flying control line airplanes in a local park. After seeing radio-controlled airplanes out at a local field, he was hooked. Unfortunately, he had no money. The modeling hobby remained dormant for many years. In 1988 his interest was rekindled and he has not looked back since. Bruce flew his first pattern contest in 1989. He has progressed through the AMA classes and is presently flying in the FAI Class. He competed in the 1994 Nationals in Masters placing fifth, and the 1995 Nationals in Masters, placing fourth. He presently flies in the FAI class. Bruce has built and flown many pattern airplanes throughout his modeling career.



Don was awestruck by RC airplanes twenty-five years ago. After seeing his first RC airplane he had to have one. Don has been building and flying ever since. He has been an inspiration to many flyers. He is an excellent teacher of both building and flying skills. Don flew in his first pattern competition in 1971 and has progressed up through the classes to FAI competition. He has been competing at this level since 1979.

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